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Proceedings

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FOR THE

Promotion of Engineering Education.

PROCEEDINGS

OF THE

SIXTH ANNUAL MEETING

HELD IN

BOSTON, MASSACHUSETTS, AUGUST 18, 19, 20, 1898.

Volume VI.

EDITED BY
THOMAS C. MENDENHALL, JOHN B. JOHNSON,
ALBERT KINGSBURY,
COMMITTEE.

PUBLISHED BY THE SOCIETY.
1898.

PRESS OF E. W. STEPHENS, COLUMBIA, MO.

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1898--9

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* This list gives only the elective members. The officers (p. v) and the past presidents (p. xxv) are members of the Council *ex officiis*.

LIST OF MEMBERS.

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
ADAMS, COMFORT A., JR. Cambridge, Mass.	Assistant Professor of Electrical Engineering, Harvard University	1894
ALDRICH, WILLIAM S. Morgantown, W. Va.	Professor of Mechanical Engineering, West Virginia University	1893
ALLEN, C. FRANK Boston, Mass.	Professor of Railroad Engineering, Massachusetts Institute of Technology	1893
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ANDERSON, F. PAUL Lexington, Ky.	Professor of Mechanical Engineering, Kentucky Agricultural and Mechanical College	1894
ANTHONY, GARDNER C. Tufts College, Mass.	Professor of Technical Drawing, Tufts College	1896
APPLEBY, WILLIAM R. Minneapolis, Minn.	Professor of Metallurgy, University of Minnesota	1896
ARNOLD, BION J. Chicago, Ill.	Consulting Electrical Engineer	1896
AYER, ARTHUR W. Burlington, Vt.	Professor of Mechanical Engineering, University of Vermont	1894
AYRES, BROWN New Orleans, La.	Professor of Physics and Electrical Engineering, Dean of College of Technology, Tulane University	1898
BAKER, IRA O. Champaign, Ill.	Professor of Civil Engineering, University of Illinois	1893
BALDWIN, WARD. Cincinnati, Ohio.	Professor of Civil Engineering, University of Cincinnati	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
BARBOUR, VOLNEY G. Burlington, Vt.	Professor of Mechanics and Bridge Engineering, Dean of Engineering Department, University of Vermont	1894
BARNEY, SAMUEL E., JR. New Haven, Conn.	Assistant Professor of Civil Engineering, Yale University	1894
BEARDSLEY, ARTHUR Swarthmore, Pa.	Professor of Engineering, Emeritus, Swarthmore College	1893
BENJAMIN, CHARLES H. Cleveland, Ohio.	Professor of Mechanical Engineering, Case School of Applied Science	1893
BEYER, T. RAYMOND State College, Pa.	Assistant Professor of Civil Engineering, Pennsylvania State College	1895
BISSELL, GEORGE W. Ames, Iowa.	Professor of Mechanical Engineering, Iowa Agricultural College	1894
BIXBY, WILLIAM H. Cincinnati, Ohio.	Major Corps of Engineers, U. S. Army, U. S. Engineer Office	1898
BOVEY, HENRY T. Montreal, Que.	Professor of Civil Engineering and Applied Mechanics, McGill University	1893
BRADFORD, JOSEPH N. Columbus, Ohio.	Associate Professor of Drawing, Ohio State University	1896
BRAY, CHARLES D. Tufts College, Mass.	Professor of Civil and Mechanical Engineering, Tufts College	1894
BRECKENRIDGE, LESTER P. Champaign, Ill.	Professor of Mechanical Engineering, University of Illinois	1893
BRILL, GEORGE M. Chicago, Ill.	Supervising Engineer, Swift & Co	1894
BROOKS, JOHN P. Lexington, Ky.	Professor of Civil Engineering, State College of Kentucky	1898
BROWN, CHARLES C. Bloomington, Ill.	Consulting Engineer	1894
BROWN, CHARLES S. Nashville, Tenn.	Professor of Mechanical Engineering, Vanderbilt University	1895
BULL, STORM Madison, Wis.	Professor of Steam Engineering, University of Wisconsin	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
BUNTE, HANS Karlsruhe, Germany.	Aulic Counselor, Professor in the Polytechnic, Director of the Institute of Chemistry and Technology and of the Grand-Ducal Experiment Station	1893
BURGESS, CHARLES Madison, Wis.	Instructor in Electrical Engineering, University of Wisconsin	1896
BURNHAM, ALTON C. Urbana, Ill.	Instructor in Mathematics, University of Illinois	1896
BURR, WILLIAM H. New York, N. Y.	Professor of Civil Engineering, Columbia University	1893
BURRAGE, SEVERANCE Lafayette, Ind.	Instructor in Sanitary Science, Purdue University	1898
BURTON, ALFRED E. Boston, Mass.	Professor of Topographical Engineering, Massachusetts Institute of Technology	1893
CALDWELL, FRANCIS C. Columbus, Ohio.	Associate Professor Electrical Engineering, Ohio State University	1897
CARPENTER, LOUIS G. Fort Collins, Colo.	Professor of Civil and Irrigation Engineering, Colorado State Agricultural College	1895
CARPENTER, ROLLA C. Ithaca, N. Y.	Professor of Experimental Engineering, Cornell University	1893
CARSON, WILLIAM W Knoxville, Tenn.	Professor of Civil Engineering, University of Tennessee	1894
CHAUVENET, REGIS Golden, Colo.	President, State School of Mines of Colorado	1896
CHRISTIANSEN, PETER Minneapolis, Minn.	Instructor of Metallurgy, University of Minnesota	1896
CHRISTY, SAMUEL B. Berkeley, Cal.	Professor of Mining and Metallurgy, University of California	1893
CLARK, GEORGE S. Highland Home, Ala.	Professor of Engineering and Physics, Highland Home College	1895

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
COLBURN, LUKE C. Laramie, Wyo.	Professor of Mechanical Engineering and Mathematics. University of Wyoming	1894
CONSTANT, FRANK H Minneapolis, Minn.	Assistant Professor of Civil Engineering, University of Minnesota.	1896
COOLEY, MORTIMER E. Ann Arbor, Mich.	Professor of Mechanical Engineering, University of Michigan	1893
CORTHELL, ELMER L. 27 Pine St., New York.	Civil Engineer	1895
CORY, HARRY T. Columbia, Mo.	Professor of Civil Engineering, Missouri State University	1895
CRAFTS, JAMES M. Boston, Mass.	President, Massachusetts Institute of Technology	1898
CRANDALL, CHARLES L. Ithaca, N. Y.	Professor of Civil Engineering. Cornell University	1893
CREIGHTON, W. H. P. New Orleans, La.	Professor of Mechanical Engineering, Tulane University	1893
CRENSHAW, BOLLING H Auburn, Ala.	Assistant in Mechanical Engineering, Alabama Polytechnic Institute	1894
CROSS, CHARLES R. Boston, Mass.	Professor of Physics, Massachusetts Institute of Technology	1895
CUMINGS, HOMER P. Schenectady, N. Y.	Instructor in Civil Engineering, Union College	1894
DANIELS, FRANK T Tufts College, Mass.	Instructor in Civil Engineering, Tufts College	1896
DE BRAY, M. Paris, France.	Professor, Ecole des Ponts et Chaussées	1893
DENISON, CHARLES S Ann Arbor, Mich.	Professor of Descriptive Geometry, Stereotomy and Drawing, University of Michigan	1893
DENTON, JAMES E. Hoboken, N. J.	Professor of Experimental Mechanics, and Superintendent of Tests. Stevens Institute of Technology	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
DENTON, FRED W. Houghton, Mich.	Mining Engineer	1894
DROWN, THOMAS M South Bethlehem, Pa.	President, Lehigh University	1895
DU BOIS, A. JAY New Haven, Conn.	Professor of Civil Engineering, Yale University	1894
DUDLEY, CHARLES B Altoona, Pa.	Chemist, Pennsylvania Railroad Company	1894
EDDY, HENRY T Minneapolis, Minn.	Professor of Mechanics, University of Minnesota	1893
EMORY, FREDERICK L Morgantown, W. Va.	Professor of Mechanics and Applied Mathematics, West Virginia University	1894
ENGLER, EDMUND A. St. Louis, Mo.	Professor of Mathematics and Dean of the Engineering School, Washington University	1897
ESTY, WILLIAM Urbana, Ill.	Associate Professor of Electrical Engineering, University of Illinois	1898
FARWELL, ELMER S Washington, D. C.	Associate Professor of Mechanical Engineering, Columbian University	1895
FLATHER, JOHN J Minneapolis, Minn.	Professor of Mechanical Engineering, University of Minnesota	1893
FLETCHER, ROBERT Hanover, N. H.	Professor of Civil Engineering, Director of Thayer School, Dartmouth College	1894
FLINT, WALTER Orono, Me.	Professor of Mechanical Engineering, University of Maine	1898
FORTH, FRANCIS C. Ashton-on-Mersey, England.	Second Lecturer in Engineering, Municipal Technical School, Manchester	1898
FOSS, FRED E. State College, Pa.	Professor of Civil Engineering, Pennsylvania State College	1893
FRANKFORTER, GEORGE B. Minneapolis, Minn.	Professor of Chemistry, University of Minnesota	1897

Name and Address.	Title.	Date of Membership.
Fuertes, Estevan A Ithaca, N. Y.	Director of College of Civil Engineering, Cornell University	1894
Fullan, M. Thomas J Auburn, Ala.	Assistant in Mechanical Engineering, Alabama Polytechnic Institute	1897
Fulton, Henry Boulder, Colo.	Professor of Civil Engineering, University of Colorado	1894
Galbraith, John Toronto, Ont.	Professor of Engineering, School of Practical Science	1893
Geer, Herbert G. Baltimore, Md.	Associate in Mechanical Engineering, Johns Hopkins University	1894
Giesecke, F. E College Station, Tex.	Professor of Drawing, Texas Agricultural and Mechanical College	1893
Gill, James H Minneapolis, Minn.	Instructor in Mechanical Engineering, University of Minnesota	1896
Goldsborough, Winder E. Lafayette, Ind.	Professor of Electrical Engineering, Purdue University	1897
Goodman, John Leeds, England.	Professor of Engineering, Yorkshire College, Victoria University	1893
Goss, William F. M Lafayette, Ind.	Professor of Experimental Engineering, Purdue University	1893
Gray, Thomas Terre Haute, Ind.	Professor of Dynamic Engineering, Rose Polytechnic Institute	1895
Grover, Nathan C Orono, Me.	Professor of Civil Engineering, University of Maine	1894
Hall, Cristopher W. Minneapolis, Minn.	Professor of Geology and Mineralogy, University of Minnesota	1894
Hamlin, George H. Orono, Me.	Civil Engineer	1895
Hampson, William B Lincoln, Neb.	Instructor in Mechanical Engineering, University of Nebraska	1896
Harris, Abram W. Orono, Me.	President, University of Maine	1897

Name and Address.	Title.	Date of Membership.
HARRIS, ELMO G. Rolla, Mo.	Professor of Engineering, Missouri School of Mines	1894
HATT, WILLIAM K. Lafayette, Ind.	Associate Professor of Applied Mechanics, Purdue University	1895
HAYNES, ARTHUR E. Minneapolis, Minn.	Professor of Mathematics, University of Minnesota	1895
HAZEN, JOHN V. Hanover, N. H.	Professor of Civil Engineering, Dartmouth College	1896
HELE-SHAW, H. L. Liverpool, Eng.	Professor of Engineering, University College	1893
HERING, HERMANN S. Baltimore, Md.	Associate in Electrical Engineering, Johns Hopkins University	1894
HIBBARD, H. WADE Ithaca, N. Y.	Principal of the Graduate School of Railway Mechanical Engineering, Sibley College, Cornell University	1896
HILL, JOHN E. Providence, R. I.	Associate Professor of Civil Engineering, Brown University	1894
HOAG, WILLIAM R. Minneapolis, Minn.	Professor of Civil Engineering, University of Minnesota	1893
HOFMAN, HEINRICH O. Boston, Mass.	Professor of Mining and Metallurgy, Massachusetts Institute of Technology	1894
HOLLIS, IRA N. Cambridge, Mass.	Professor of Engineering, Harvard University	1894
HOOD, OZNI P. Houghton, Mich.	Professor of Mechanical and Electrical Engineering, Michigan College of Mines	1893
HOSKINS, LEANDER M. Stanford University, Cal.	Professor of Applied Mechanics, Leland Stanford Junior University	1893
HOWE, MALVERD A. Terre Haute, Ind.	Professor of Civil Engineering, Rose Polytechnic Institute	1894
HUME, ALFRED McMinniville, Tenn.		1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
HUMPHREYS, DAVID C. Lexington, Va.	Professor of Civil Engineering, Washington and Lee University	1893
HUTTON, FREDERICK R. New York, N. Y.	Professor of Mechanical Engineering, Columbia University	1894
JACKSON, DUGALD C. Madison, Wis.	Professor of Electrical Engineering, University of Wisconsin	1893
JACKSON, JOHN P State College, Pa.	Professor of Electrical Engineering, Pennsylvania State College	1894
JACOBUS, D. S. Hoboken, N. J.	Professor of Experimental Mechanics and Engineering Physics, Stevens Institute of Technology	1893
JACOBY, HENRY S. Ithaca, N. Y.	Associate Professor of Bridge Engineering and Graphics, Cornell University	1894
JOHNSON, JOHN B. St. Louis, Mo.	Professor of Civil Engineering, Washington University	1893
JOHNSON, LEWIS J. Cambridge, Mass.	Assistant Professor of Civil Engineering, Lawrence Scientific School, Harvard University	1898
JONES, CLEMENT R. Morgantown, W. Va.	Assistant in Mechanical Engineering, West Virginia University	1895
JONES, FORREST R. Madison, Wis.	Professor of Machine Design, University of Wisconsin	1893
KAY, EDGAR B. Ithaca, N. Y.	Instructor in Civil Engineering, Cornell University	1898
KEENE, EDWARD S. Fargo, N. Dak.	Professor of Mechanics, North Dakota Agricultural College	1894
KENT, WILLIAM Passaic, N. J.	Consulting Engineer, Associate Editor of "Engineering News," New York City	1894
KIDWELL, EDGAR Hancock, Mich.	Superintendent, Arcadian Copper Mining Company	1896

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
KIMBALL, RODNEY G. Brooklyn, N. Y.	Professor of Applied Mathematics, The Polytechnic Institute of Brooklyn	1894
KINEALY, J. H. St. Louis, Mo.	Professor of Mechanical Engineering, Washington University	1893
KINGSBURY, ALBERT. Durham, N. H.	Professor of Mechanical Engineering, New Hampshire College of Agriculture and the Mechanic Arts	1893
KIRCHNER, WILLIAM H. Minneapolis, Minn.	Assistant Professor of Drawing, University of Minnesota	1896
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KYSER, HENRY H Auburn, Ala.	Instructor in Physics, Director of Physical Laboratory, Alabama Polytechnic Institute.	1897
LAMBERT, PRESTON A South Bethlehem, Pa.	Assistant Professor of Mathematics, Lehigh University	1897
LANDRETH, OLIN H. Schenectady, N. Y.	Professor of Civil Engineering, Union College	1893
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LANZA, GAETANO Boston, Mass.	Professor of Applied Mechanics, in charge of the Department of Mechanical Engineering, Massachusetts Institute of Technology	1893
LARDNER, HENRY A. New York, N. Y.	Electrical Engineer, N. Y. Heat, Light and Power Company, No. 37 Gold St.	1895
LAWRENCE, JAMES W. Fort Collins, Colo.	Professor of Mechanical Engineering, State Agricultural College	1898
LYON, JOSEPH P. Rochester, N. Y.	Assistant Engineer. Erie Railroad Company. No. 102 Chestnut St.	1894
McCLINTOCK, WILLIAM E. Boston, Mass.	Civil Engineer; Instructor in Highway Engineering, Harvard University, Cambridge, Mass.; No. 15 Court Square, Boston, Mass.	1898

Name and Address.	Title.	Date of Membership.
McColl, Jay R. Knoxville, Tenn.	Professor of Mechanical Engineering, University of Tennessee	1894
McKissick, Anthony F. Auburn, Ala.	Professor of Electrical Engineering, Alabama Polytechnic Institute	1897
McNair, Fred W. Houghton, Mich.	Professor of Mathematics and Physics, Michigan College of Mines.	1897
McRae, Austin L. St. Louis, Mo.	Consulting Electrical Engineer	1894
Magowan, Charles S. Iowa City, Iowa.	Assistant Professor of Civil Engineering, State University of Iowa.	1896
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Marx, Christian W. Columbia, Mo.	Professor of Mechanical Engineering, Missouri State University	1894
Mather, Thomas W. New Haven, Conn.	Principal, Boardman Manual Training High School	1894
Mathews, Hubert B Brookings, S. Dak.	Professor of Physics, South Dakota Agricultural College	1896
Matthews, Charles P. Lafayette, Ind.	Associate Professor of Electrical Engineering, Purdue University	1898

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
MAURER, EDWARD R. Madison, Wis.	Assistant Professor of Theoretical and Applied Mechanics, University of Wisconsin	1897
MEES, CARL L. Terre Haute, Ind.	President, Rose Polytechnic Institute	1894
MENDENHALL, THOMAS C. Worcester, Mass.	President, Worcester Polytechnic Institute	1895
MERRIMAN, MANSFIELD South Bethlehem, Pa.	Professor of Civil Engineering, Lehigh University	1893
MORLEY, FRED Lafayette, Ind.	Professor of Civil Engineering, Purdue University	1896
MUNROE, HENRY S. New York, N. Y.	Professor of Mining, Columbia University	1893
MURKLAND, CHARLES S. Durham, N. H.	President, New Hampshire College of Agriculture and the Mechanic Arts	1894
NAGLE, JAMES C. College Station, Tex.	Professor of Civil Engineering and Physics, Agricultural and Mechanical College of Texas	1897
NEFF, FRANK H. Cleveland, Ohio.	Assistant Professor of Civil Engineering, Case School of Applied Science.	1895
ORDWAY, JOHN M. New Orleans, La.	Professor of Applied Chemistry, Acting Professor of Civil Engineering, Tulane University	1894
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OWENS, ROBERT B. Montreal, Que.	Professor of Electrical Engineering, McGill University	1894
PATTERSON, GEORGE W., JR. Ann Arbor, Mich.	Assistant Professor of Physics. University of Michigan	1896
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NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
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PETTEE, CHARLES H. Durham, N. H.	Professor of Mathematics, New Hampshire College	1898
PORTER, DWIGHT Boston, Mass.	Professor of Hydraulic Engineering, Massachusetts Institute of Technology	1893
PORTER, J. MADISON Easton, Pa.	Professor of Civil Engineering, Lafayette College	1893
PUPIN, MICHAEL I. New York, N. Y.	Adjunct Professor of Mechanics, Columbia University	1895
RANDOLPH, LINGAN S. Blacksburg, Va.	Professor of Mechanical Engineering, Virginia Polytechnic Institute	1894
RAYMOND, WILLIAM G. Troy, N. Y.	Professor of Geodesy and Road Engineering, Rensselaer Polytechnic Institute	1893
REBER, LOUIS E. State College Pa.	Professor of Mechanical Engineering, Pennsylvania State College	1893
RICE, ARTHUR L. Brooklyn, N. Y.	In charge of Departments of Steam Engineering and Electricity, Pratt Institute	1894
RICHARDS, CHARLES R. Lincoln, Neb.	Professor of Practical Mechanics and Director of the School of Mechanic Arts, University of Nebraska.	1895
RICHARDS, ROBERT H Boston, Mass.	Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology.	1895
RICHTER, ARTHUR W. Madison, Wis.	Assistant Professor of Steam Engineering, University of Wisconsin	1894
RICKER, NATHAN C. Urbana, Ill.	Dean of College of Engineering, University of Illinois	1894
RICKETTS, PALMER C. Troy, N. Y.	Director, Rensselaer Polytechnic Institute	1893

Name and Address.	Title.	Date of Membership.
Riggs. Walter M. Clemson College, S. C.	Instructor in Electrical Engineering, in charge of Electrical Laboratories, Clemson Agricultural College.	1897
Ripper, William Sheffield, Eng.	Professor of Engineering, Principal, The Technical School.	1893
Ritter, C. Wilhelm Zurich, Switzerland.	Professor of Civil Engineering, Federal Swiss Polytechnic.	1893
Robbins, Arthur G. Boston, Mass.	Assistant Professor of Civil Engineering, Massachusetts Institute of Technology.	1894
Robinson, Frederic H Newark, Del.	Professor of Civil Engineering, Delaware College.	1894
Robinson, Stillman W. Columbus, Ohio.	Mechanical Engineer and Expert.	1893
Rosebrugh, Thomas R. Toronto, Ontario.	Lecturer in Electrical Engineering, School of Practical Science	1896
Sackett, Robert L. Richmond, Ind.	Professor of Applied Mathematics and Astronomy, Earlham College.	1893
Schuerman, William H. Nashville, Tenn.	Professor of Civil Engineering, Vanderbilt University.	1895
Sedgwick, William T. Boston, Mass.	Professor of Biology, Massachusetts Institute of Technology	1896
Shepardson, George D. Minneapolis, Minn.	Professor of Electrical Engineering, University of Minnesota.	1895
Smart, Richard A. Lafayette, Ind.	Instructor in Engineering Laboratory, Purdue University.	1896
Smith, Harold B. Worcester, Mass.	Professor of Electrical Engineering, Worcester Polytechnic Institute.	1898
Smith, Harry E. Minneapolis, Minn.	Assistant Professor of Mechanical Engineering, University of Minnesota.	1895
Smith, Herbert S. S. Princeton, N. J.	Assistant Professor of Civil Engineering, Princeton University.	1894

Name and Address.	Title.	Date of Membership.
Snow, Charles H. New York, N. Y.	Dean of School of Civil Engineering, New York University	1895
Solberg, Halvor C. Brookings, S. D.	Professor of Mechanical Engineering, South Dakota Agricultural College	1894
Spalding, Frederick P. Ithaca, N. Y.	Assistant Professor of Civil Engineering. Cornell University	1893
Spangler, H. W. Philadelphia, Pa.	Professor of Mechanical Engineering, University of Pennsylvania	1893
Sperr, Frederick W. Houghton, Mich.	Professor of Civil and Mining Engineering, Michigan College of Mines.	1896
Springer, Frank W. Minneapolis, Minn.	Instructor in Electrical Engineering, University of Minnesota	1896
Staley, Cady Cleveland, Ohio.	President, Case School of Applied Science	1894
Stanwood, James B. Cincinnati, Ohio.	Director, Technical School of Cincinnati	1894
Stevens, James S. Orono, Me.	Professor of Physics, University of Maine	1898
Stewart, Clinton B Chicago, Ill.	Civil Engineer, 2501 Magnolia Ave	1894
Stewart, Lewis B. Toronto, Ontario.	Lecturer in Surveying, School of Practical Science	1897
Stout, Oscar Van P Lincoln, Neb.	Associate Professor of Civil Engineering, University of Nebraska	1894
Stratton, Samuel W. Chicago, Ill.	Associate Professor of Physics, University of Chicago	1893
Stubbs, Joseph E. Reno, Nev.	President, Nevada State University	1897
Swain, George F. Boston, Mass.	Professor of Civil Engineering, Massachusetts Institute of Technology	1893
Talbot, Arthur N Champaign, Ill.	Professor of Municipal Engineering, University of Illinois	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
TAYLOR, WILLIAM D....... Baton Rouge, La.	Professor of Physics and Engineering, Louisiana State University........	1894
THOMAS, ROBERT G....... Charleston, S. C.	Professor of Mathematics and Engineering, South Carolina Military Academy..	1894
THORNBURG, CHARLES L... South Bethlehem, Pa.	Professor of Mathematics, Lehigh University........	1894
THURSTON, ROBERT H.... Ithaca, N. Y.	Director of Sibley College, Cornell University............. ...	1893
TIMMERMAN, ARTHUR H... Rolla, Mo.	Professor of Physics, School of Mines and Metallurgy, University of Missouri...........	1894
TOWLE, WILLIAM M. ..... State College, Pa.	Assistant Professor of Practical Mechanics, Pennsylvania State College	1895
TRAMMEL, ROBERT J....... Auburn, Ala.	Instructor in Mechanical Department, Alabama Polytechnic Institute	1896
TURNEAURE, FREDERICK E. Madison, Wis.	Professor of Bridge and Hydraulic Engineering, University of Wisconsin.	1894
TURNER, DANIEL L........ Cambridge, Mass.	Instructor in Surveying and Hydraulics, Lawrence Scientific School, Harvard University	1898
TYLER, HARRY W....... ... Boston, Mass.	Professor of Mathematics, and Secretary, Massachusetts Institute of Technology	1894
UNWIN, WM. CAWTHORNE.. London, England.	Professor of Engineering, City and Guilds of London Central Institution	1893
VAN DAELL, ALPHONSE N.. Boston, Mass.	Professor of Modern Languages, Massachusetts Institute of Technology	1897
VAN ORNUM, J. L.......... Newburgh, N. Y.	Civil Engineer	1895
VEDDER, HERMAN K....... Agricultural College, Mich.	Professor of Mathematics and Civil Engineering, Michigan State Agricultural College	1894

Name and Address.	Title.	Date of Membership.
Voit, Ernst Munich, Bavaria.	Professor of Physics and Electricity, Koenigliches Polytechnikum	1894
Waddell, J. A. L. Kansas City, Mo.	Consulting Bridge Engineer	1893
Wadsworth, Joel E. Middletown, Conn.	Civil Engineer	1895
Wadsworth, M. Edward Houghton, Mich.	President, Michigan College of Mines	1895
Wagner, John R. Drifton. Pa.	Superintendent of Motive Power, D., S. & S. R. R.	1894
Waldo, Clarence A. Lafayette, Ind.	Professor of Mathematics, Purdue University	1897
Walker, Elton D. Schenectady, N. Y.	Instructor in Engineering, Union College	1895
Webb, Howard S. Orono, Me.	Instructor in Mechanical Engineering, University of Maine	1897
Wells, James H. Lexington, Ky.	Assistant Professor of Mechanical Engineering, Kentucky Agricultural and Mechanical College	1897
Wernicke, Paul Lexington, Ky.	Professor of Modern Languages, Kentucky Agricultural and Mechanical College	1897
Whipple, George C Brooklyn, N. Y.	Director of Mt. Prospect Laboratory, Flatbush Ave. and Eastern Parkway	1896
White, George H. Worcester, Mass.	Professor of Civil Engineering, Worcester Polytechnic Institute	1896
Whitney, Nelson O Madison, Wis.	Professor of Railway Engineering, University of Wisconsin	1893
Wilcox, Ralph M. South Bethlehem, Pa.	Instructor in Civil Engineering, Lehigh University	1894
Willett, James R Chicago, Ill.	Architect, 434 Jackson Boulevard	1896

Name and Address.	Title.	Date of Membership.
Williams, Sylvester N... Mt. Vernon, Iowa.	Professor of Civil Engineering, Cornell College...	1893
Williston, Arthur L.... Columbus, Ohio.	Director of Industrial Department, Ohio State University	1897
Wilmore, John J. ... ... Auburn, Ala.	Professor of Mechanical Engineering, Alabama Polytechnic Institute.....	1894
Wilson, Victor T .... Ithaca, N. Y.	Instructor in Freehand and Mechanical Drawing, Cornell University....	1898
Wing, Charles B.. ...... Stanford University, Cal.	Professor of Structural Engineering, Leland Stauford Junior University..	1895
Wood, Arthur J......... New York, N. Y.	Associate Editor "Railroad Gazette," 32 Park Place..........	1898
Woodward, Calvin M... St. Louis, Mo.	Professor of Applied Mechanics, and Dean of Faculty of Pure Science, Washington University	1894
Woodward, Robert S.... New York, N. Y.	Professor of Mechanics, Columbia University	1893
Wright, Charles H. C... Toronto, Ontario.	Lecturer in Architecture, School of Practical Science	1897
Ziwett, Alexander .... Ann Arbor, Mich.	Assistant Professor of Mathematics, University of Michigan	1897

DISTRIBUTION OF MEMBERS.

Alabama	6
Arkansas	1
California	4
Colorado	4
Connecticut	4
Delaware	1
Idaho	1
Illinois	13
Indiana	13
Iowa	4
Kansas	1
Kentucky	4
Louisiana	4
Maine	7
Maryland	2
Massachusetts	27
Michigan	10
Minnesota	14
Mississippi	1
Missouri	10
Nebraska	3
Nevada	1
New Hampshire	5
New Jersey	4
New York	29
North Dakota	1
Ohio	11
Pennsylvania	16
Rhode Island	1
South Carolina	2
South Dakota	2
Tennessee	4
Texas	2
Vermont	2
Virginia	2
West Virginia	3
Wisconsin	8
Wyoming	1
Distr. of Columbia	1
Canada	6
England	5
France	1
Switzerland	1
Germany	2
Total	244

38 States, the District of Columbia, Canada, and 4 European Countries.

PAST OFFICERS.

Special Committee for Division E, (Engineering Education), World's Engineering Congress, 1893.

IRA O. BAKER, Chairman	HENRY T. EDDY, Vice-Chairman
WM. R. HOAG, Secretary	C. FRANK ALLEN, Secretary, *pro tem*
MORTIMER E. COOLEY	SAMUEL W. STRATTON
	STORM BULL

PRESIDENTS.

DE VOLSON WOOD,* 1893–4	MANSFIELD MERRIMAN, 1895–6
GEORGE F. SWAIN, 1894–5	HENRY T. EDDY, 1896–7
JOHN B. JOHNSON, 1897–8.	

VICE-PRESIDENTS.

SAMUEL B. CHRISTY, GEORGE F. SWAIN, 1893–4
ROBERT H. THURSTON, FRANK O. MARVIN, 1894–5
FRANK O. MARVIN, CADY STALEY, 1895–6
JOHN GALBRAITH, JOHN M. ORDWAY, 1896–7
THOMAS C. MENDENHALL, HARRY W. TYLER, 1897–8

TREASURER.

STORM BULL, 1893–5

SECRETARIES.

JOHN B. JOHNSON, 1893–5 C. FRANK ALLEN, 1895–7

MEMBERS OF PREVIOUS COUNCILS.

Terms of Office Expired in 1894.

M. E. COOLEY	H. T. EDDY	W. F. M. GOSS
W. R. HOAG	S. W. ROBINSON	H. W. SPANGLER
	R. H. THURSTON	

Terms of Office Expired in 1895.

H. T. BOVEY	W. H. BURR	O. H. LANDRETH
MANSFIELD MERRIMAN	W. G. RAYMOND	G. F. SWAIN
	DE VOLSON WOOD*	

Terms of Office Expired in 1896.

I. O. BAKER	STORM BULL	S. B. CHRISTY
JOHN GALBRAITH	J. B. JOHNSON	F. O. MARVIN
	C. D. MARX	

Terms of Office Expired in 1897.

H. T. EDDY	J. J. FLATHER	J. P. JACKSON
ALBERT KINGSBURY	L. S. RANDOLPH	S. W. ROBINSON
	R. H. THURSTON	

Terms of Office Expired in 1898.

C. F. ALLEN	C. L. MEES	MANSFIELD MERRIMAN
J. M. ORDWAY	W. G. RAYMOND	CADY STALEY
	R. S. WOODWARD	

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*Died, June 27, 1897.

CONSTITUTION

OF THE

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

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1. NAME.—This organization shall be called the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

2. MEMBERS.—Members of the Society shall be those who occupy, or have occupied, responsible positions in the work of engineering instruction, together with such other persons as may be recommended by the Council.

Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. They shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues.

The name of each candidate for membership shall be proposed in writing to the Council by two members to whom he is personally known. Such names, if approved by the Council, shall be voted on by the Society at the annual meetings.

3. OFFICERS.—There shall be a President, two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year. They shall be chosen by vote of the members at the annual meeting.

4. COUNCIL.—The Council of this Society shall consist of twenty-one elective members, one third of whom shall retire annually. The officers and the past Presidents of the Society shall be members of the Council, *ex officiis*.

Any member of this Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass ou proposals for membership, attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

5. Fees and Dues.—The admission fee shall be three dollars, and the annual dues three dollars, payable at the time of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the proceedings, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who shall be in arrears more than two years and shall have been duly notified by the Secretary, shall be thereby dropped from the roll, excepting such arrearage shall be paid previous to the next ensuing annual meeting; and no such member shall be restored until he has paid his arrears.

6. Meetings.—There shall be a regular meeting occurring at the time and place of the meeting of the American Association for the Advancement of Science, or of some one of the National Engineering Societies, or otherwise as the Council may determine.

7. Publication.—The proceedings of the Society, and such papers or abstracts as may be approved by the Council, shall be published as soon as possible after each annual meeting.

8. Amendments.—This Constitution may be amended by a two-thirds vote at any regular meeting, after being approved by a two-thirds vote of the Council, taken by letter ballot.

RULES GOVERNING THE COUNCIL.

First. The officers of the Society shall constitute a committee to arrange the time and place of the annual meeting, and also to prepare a program for the same.

Second. The reading of papers shall be limited to fifteen minutes each, and abstracts of the same of about three hundred words or less shall be printed when practicable and distributed in advance to the members.

Third. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

PROCEEDINGS.

The sixth annual meeting of the Society for the Promotion of Engineering Education was held at the Massachusetts Institute of Technology, Boston, Massachusetts, August 18, 19, and 20, 1898, immediately preceding the meeting of the American Association for the Advancement of Science.

THURSDAY, AUGUST 18, 1898—Morning Session, 9:30 O'Clock.

The meeting was called to order by the President, Professor John B. Johnson.

The reports of the Secretary and the Treasurer were read and accepted. Professors C. Frank Allen and Storm Bull were appointed Auditing Committee.

The election of new members was next taken up, and the following applicants were elected: John P. Brooks, William Esty, Walter Flint, Edgar B. Kay, Julius J. Knoch, James W. Lawrence, James S. Stevens, Victor T. Wilson, and Arthur J. Wood.

It was unanimously voted to amend section 8 of the Constitution by striking out the clause "there shall be no annual dues, however, for members residing outside of North America."

The annual address was then delivered by the President, Professor John B. Johnson. This was fol-

Library
N. C. State College

lowed by Professor Gaetano Lanza's paper, "The Class Room and the Laboratory in their Mutual Adjustment to the End of the Most Efficient Instruction," which was read by the author, the following members taking part in the discussion of the paper: Kent, Johnson, Flather, Hibbard, Fletcher, Swain, Hollis, and Lanza.

Professor Harold B. Smith then read his paper, "Note on the Organization of an Electrical Engineering Laboratory;" after which Professor John J. Wilmore's paper, "Some Phases of Engineering Education in the South," was read by the Secretary.

Before adjournment, a Nominating Committee was appointed, consisting of Professors Swain, Eddy, and Marburg.

The afternoon was spent in visiting the various buildings of the Massachusetts Institute of Technology.

Evening Session, 7:30 O'Clock.

But one paper was presented at this session,—"On the Organization of Engineering Courses, and on Entrance Requirements for Professional Schools." This was read by the author, Professor Robert H. Thurston. The discussion of the paper was deferred until the morning session.

FRIDAY, AUGUST 19—Morning Session, 9:30 O'Clock.

The first business taken up was the election of new members, and the following applicants were declared elected: Brown Ayres, William H. Bixby, Severance Burrage, Francis C. Forth, Lewis J. Johnson, William E. McClintock, Charles H. Pettee, and Harold B. Smith.

The following members, whose names were presented by the Nominating Committee, were unanimously elected members of the Council: Thomas M. Drown, Lehigh University; Malverd A. Howe, Rose Polytechnic Institute: Ira N. Hollis, Harvard University; Gaetano Lanza, Massachusetts Institute of Technology; Palmer C. Ricketts, Rensselaer Polytechnic Institute; Robert G. Thomas, South Carolina Military Academy; Calvin M. Woodward, Washington University.

Professor Mendenhall made a brief statement concerning the work of the Massachusetts Highway Commission, and placed at the disposal of the membership printed descriptions of methods of testing road-building stone.

The discussion of Professor Thurston's paper, which had been read the previous evening, was then taken up, the following members taking part: J. B. Johnson, C. M. Woodward, Kent, Fletcher, and Ayres.

This was followed by Professor Haynes' paper, "The Mounting and Use of a Spherical Blackboard," which was read by Professor Eddy and discussed by Professors J. B. Johnson and Mendenhall.

The report of the Committee on Uniformity of Symbols was presented by the Chairman, Professor Mendenhall.

After some discussion, it was voted that the report be accepted and the Committee discharged; that the recommendation of the Committee, that no action on uniformity of symbols be taken by the Society at this time, be adopted: and that the recommendation to appoint a new committee, to report on fundamental quantities used in engineering, be referred to the incoming Council with power to act.

Professor J. P. Jackson then read his paper, "Electricity in Engineering Courses Other than Electrical." The paper was discussed by Professors Hibbard, Randolph, Caldwell, Bull, Adams, Marburg, and Jackson.

The paper on "A Course in Industrial Chemistry for Technical Schools" was read by the author, Dr. F. L. Dunlap, and was discussed by Professors Bull, Ayres, H. P. Talbot, F. H. Robinson, and Caldwell.

The Secretary read Professor Hatt's paper,* entitled "A Laboratory Apparatus for Impact Experiments." The paper was discussed by Professors J. B. Johnson, Galbraith, and Gray.

The meeting then adjourned.

In the afternoon a large party of the members were guests of the Metropolitan Elevated Railway Company. A special car carried the party throughout the subway system, this being the first passenger car to traverse the entire system. The trip included a visit to the West End Power Station of the Company.

EVENING SESSION, 7:30 O'Clock.

The first paper of the session was, "The Direct Study of Thermodynamics," which was read by the author, Professor Sydney A. Reeve. The paper was discussed by the following members: Peabody, Eddy, Kent, Galbraith, and Adams.

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* Not printed in the Proceedings, having been withdrawn by the author.

Professor H. W. Tyler, Chairman of the Committee on Entrance Requirements, read the report of that Committee. The report was accepted, action upon the recommendations being deferred till the business meeting of the next session.

Professor W. R. Hoag then read his paper, "A Course in Highway Engineering for Civil Engineers," which was discussed by Professor Allen.

The meeting then adjourned.

SATURDAY, AUGUST 20—Morning Session, 9:30 O'Clock.

Upon the formal recommendation by the Council, James M. Crafts, Daniel L. Turner, and Charles P. Matthews were elected members of the Society.

Professor W. T. Sedgwick then spoke on the subject "The Claims of Sanitary Science to a Place in the Curriculum of Engineering Education." In the discussion that followed, Professors Merriman, Burrage, Sackett, J. B. Johnson, and Mr. Kent took part.

The deferred discussion of the Report of the Committee on Entrance Requirements was next taken up. After brief discussions by Professors Tyler, Allen, and J. B. Johnson, motion was made to refer the recommendations of the Committee to the Council with power to act. After some further discussion the motion was carried unanimously.

Then followed the reading of Professor Edgar Marburg's paper on "Undergraduate Thesis Work," which was read by the author and discussed by Professors L. J. Johnson, J. P. Jackson, F. H. Robinson, Gray, and Marburg.

Professor H. S. Jacoby's paper on "The Construction of Models by Students as an Aid in Teaching Descriptive Geometry" was read by Professor Crandall and discussed by Professors Bull and Kingsbury.

Owing to the approach of the hour for adjournment, Professor James C. Nagle's paper on "The Training of Engineers for the Maintenance of Way Department on Railroads" was read by abstract only by the author. The paper was discussed by Professors Allen and Whitney.

Professor Francis C. Caldwell then read his paper, "Notes on some Methods in use in an Engineering Laboratory."

Two amendments to the Constitution, which were unanimously recommended by the Council, were then adopted by unanimous vote of the Society. The recommendations were as follows:

To amend section 2 of the Constitution by inserting the following paragraph between the first and second paragraphs:

"Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. They shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues."

To amend section 8 so that it shall read: "This Constitution may be amended by a two-thirds vote at any regular meeting, after being approved by a two-thirds vote of the Council, taken by letter ballot."

Upon the presentation of the report of the Nominating Committee, the following officers were elected:

President: THOMAS C. MENDENHALL, Worcester Polytechnic Institute.
Vice-Presidents: C. FRANK ALLEN, Massachusetts Institute of Technology.
H. W. SPANGLER, University of Pennsylvania.
Treasurer: JOHN J. FLATHER, University of Minnesota.
Secretary: ALBERT KINGSBURY, New Hampshire College.

Before the adjournment of the meeting, the Society passed a vote in recognition of the many courtesies that had been shown to the Society and to its individual members during the meeting. The thanks of the Society were extended to the President and Faculty of the Massachusetts Institute of Technology; the officers of the Technology Club; the Boston Society of Civil Engineers; the Boston Elevated Railway Company; the officers of the Street Department of the City of Boston; the Metropolitan Sewage Commission; the New England Telephone and Telegraph Company; and the Western Union Telegraph Company.

The afternoon was devoted to an excursion in the harbor, a boat being provided for the purpose by the officers of the Street Department of the City of Boston. The trip included visits to the outfall sewers and sewage pumping stations of the Metropolitan system.

The meeting thus brought to a close was the most largely attended since the Brooklyn meeting of 1894. Twenty new members were admitted, and the register of the meeting shows that sixty-nine members attended, as follows:

Adams, C. A., Jr.
Allen, C. F.
Ames, W. L.
Anderson, F. P.
Anthony, G. C.
Ayres, B.
Bray, C. D.
Brooks, J. P.
Bull, S.
Burrage, S.
Caldwell, F. C.
Constant, F. H.
Crandall, C. L.
Cross, C. R.
Eddy, H. T.
Esty, W.
Farwell, E. S.
Flather, J. J.
Fletcher, R.
Galbraith, J.
Giesecke, F. E.
Gray, T.
Grover, N. C.
Harris, A. W.
Hibbard, H. W.
Hoag, W. R.
Hofman, H. O.
Hollis, I. N.
Howe, M. A.
Jackson, J. P.
Johnson, J. B.
Johnson, L. J.
Jones, F. R.
Kent, W.
Kingsbury, A.
Lambert, P. A.
Landreth, O. H.
Lanza, G.
McNair, F. W.
Marburg, E.
Marvin, F. O.
Mendenhall, T. C.
Merriman, M.
Nagle, J. C.
Ostrander, J. E.
Peabody, C. H.
Pettee, C. H.
Porter, J. M.
Randolph, L. S.
Rice, A. L.
Richards, R. H.
Richter, A. W.
Robbins, A. G.
Robinson, F. H.
Sackett, R. L.
Sedgwick, W. T.
Stevens, J. S.
Swain, G. F.
Thomas, R. G.
Thurston, R. H.
Towle, W. H.
Turneaure, F. E.
Tyler, H. W.
Van Daell, A. N.
Walker, E. D.
White, G. H.
Wood, A. J.
Woodward, C. M.
Woodward, R. S.

REPORT OF THE SECRETARY.

The Society for the Promotion of Engineering Education, at the beginning of the sixth year of its existence, is attended with abundant evidence of the increase of its vigor and the extension of its usefulness. The unabated interest of the members of the Society; the additions to the membership; the continued demand for the Proceedings; and the publicity given to the work of the Society through the technical press,—all bear witness of the value of our organization.

The membership list for the past year shows that the Society numbers two hundred and twenty-six members, an increase of twenty-three over the previous year.

There has been a change in the membership of the Committee on Entrance Requirements, owing to the resignation of Professor F. O. Marvin from the Committee. Professor Marvin had been chairman of the Committee since its appointment at the Brooklyn meeting, in 1894. President Johnson appointed Professor H. W. Tyler, who was one of the original members of the Committee, to succeed Professor Marvin as chairman, and appointed Professor T. C. Mendenhall to be a member of the

Committee; and these members accepted their duties in March of the present year.

In response to an invitation from the Corporation and the Faculty of the Massachusetts Institute of Technology, President Johnson appointed a delegation of five members of the Society to attend the memorial exercises in honor of General Francis Amasa Walker, LL. D., late President of the Institute. A report of the attendance of the delegation, made by Professor I. N. Hollis, chairman of the delegation, is appended.

Respectfully submitted,

ALBERT KINGSBURY, Secretary.

CAMBRIDGE, MASS., August 16, 1898.

Professor J. B. Johnson, President of the Society for the Promotion of Engineering Education.

MY DEAR SIR: I respectfully inform you that the society was represented at the memorial meeting in honor of the late President Francis A. Walker by Professors Mansfield, Merriman, Henry W. Spangler, William G. Raymond, and Ira N. Hollis. Professor James E. Denton, the fifth member of the Committee appointed by you, was unavoidably detained in New York. The meeting was held at Music Hall, Boston, Massachusetts, on October 14, 1897. At the invitation of the Corporation and Faculty of the Massachusetts Institute of Technology, Mr. Augustus Lowell, Governor Roger Wolcott, and Senator George F. Hoar addressed a large audience composed of the faculty, alumni, and students of the Institute, and representatives of many educational and scientific bodies. The address of Senator Hoar was exceptionally eloquent and touching in its references to General Walker's life work.

I can not refrain from adding that although he was not a member of our society we have suffered a personal loss. His death at the very height of usefulness to the cause we have so deeply at heart closed an enviable career and deprived us of a sturdy champion. Our country will find it difficult to replace him.

I remain yours very respectfully,

IRA N. HOLLIS.

REPORT OF THE TREASURER.

The Treasurer of this Society would respectfully report as follows:

The total receipts during the year 1897–1898, from various sources as given in the itemized statements herewith, have been $1,250.84, of which $528 was for current dues. There is at present a balance of $423.72 on hand; but, to offset this, there are several unpaid bills, including those for printing and binding Volume V of the annual Proceedings, which amount to about $450; however, there is yet due to the Society an amount which will cover all outstanding bills, and the Treasurer is pleased to report that there is no actual deficit.

During the year, $56.25 was received from the sale of the Society's Proceedings, and $153 from initiation fees and dues from new members.

A condensed statement of receipts and disbursements for the year is appended herewith:

RECEIPTS.

By Cash on hand August 16, 1897	$ 542.75
By Sale of Transactions	56.25
By Reprints of Author's Papers	4.84
By Initiation Fees	75.00
By Past Dues	40.00
By Advance Dues	4.00
By Current Dues	528.00
Total	$1,250.84

DISBURSEMENTS.

To Stenographer's Services, Toronto Meeting	$ 75.00
To Printing Transactions, Reprint and Circulars	597.64
To Postage and Stationery	32.49
To Express, Freight, Telegrams	15.22
To Incidental Expenses	32.30
To Expenses of Committee on Entrance Requirements	69.87
To Exchange on Checks	4.60
To Cash on Hand	423.72
Total	$1,250.84

August 18, 1898.

JOHN J. FLATHER,
Treasurer.

PRESIDENT'S ADDRESS: A HIGHER INDUSTRIAL AND COMMERCIAL EDUCATION AS AN ESSENTIAL CONDITION OF OUR FUTURE MATERIAL PROSPERITY.

BY JOHN B. JOHNSON.
Professor of Civil Engineering, Washington University, St. Louis, Mo.

PREFACE.

In thanking you for the honor you have conferred upon me in selecting me to preside over your councils at this our sixth annual meeting, I wish to give some expression to the feeling of responsibility I have always felt as a member of this Society. I believe the manufacturing and commercial prosperity of our country is directly dependent upon the technical education of our people, and so far as this Society has taken upon itself the shaping and the development of this education, so far are we, as members of this body, responsible for the results attained. This feeling will explain, also, my choice of a subject for this address.

While the material prosperity of any country is not the ultimate highest good, it is the foundation of the happiness and of the progressive enlightenment of its people. To learn the essential conditions of such a prosperity, therefore, is a matter of supreme importance. I invite your attention to-day to what I conceive to be one of these essential conditions. So far as these conditions consist of educational opportunities and advantages, so far they are properly presented to, and considered by, this Society, which now very largely directs the present methods and will direct the future policy of the technical instruction in America. In approaching this subject we are at once impressed with the conviction that the teachings of history are not available to serve as a guide in this matter.

We are living in a new world; old things are done away, and all things have become new. In the former times all knowledge of material things was traditional and had to be learned by the traditional methods; to-day nearly all such knowledge is scientific, and should be acquired by scientific methods. Formerly the industries were directed by mechanics who, by a long apprenticeship, had slowly acquired the manual methods of their predecessors; to-day they are most successfully guided by men of large scientific attainments; and in the near future such scientific direction will be absolutely essential wherever there is free competition in the market to be supplied. Prosperity, or even supremacy, in material things in the past, is therefore no promise of such a position in the future, and as a proof of this we have but to compare the past achievements of England and its present subordination to Germany.

PAST COMMERCIAL SUPREMACY OF ENGLAND.

For the past three hundred years England has labored systematically to encourage all her sources of material prosperity.* By special charters to commercial and manufacturing companies; by minutely elaborate laws governing apprentices, their terms of employment, and their wages; by high and often exclusive protective tariffs; by subsidies and by exclusive trading privileges granted to navigation companies; by the importation of skilled workmen from Holland; by receiving the Huguenot refugees from France, and by the prevention of the emigration of skilled mechanics; by her coal and iron deposits; by her early development of the steam engine and its application to the various industries, including railroads and steamships; by the industrious habits and the aggressive disposition of her people; by her honesty in governmental and business relations; by parliamentary commissions without number, and with a continuous and consistent policy on the part of the whole people of England, she succeeded finally in absorbing most of the manufacturing and in carrying nearly all of the commerce of the world.

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* See Cunningham's *Growth of English Industry and Commerce*, 1892.

Holland's commercial supremacy disappeared with the loss of her navies by war, and the one-time industrial supremacy of France always lacked the necessary shipping to bring her products to the four corners of the globe as England has been able to do. Finally, by adopting a free-trade policy, when her interests were mostly centered in foreign countries, her manufacturing industries obtained such an impetus that it seemed England would long remain the leading manufacturing country of the world. In this conviction her people have placidly followed in the footsteps of their fathers well assured that nothing could shake the commercial, Gibraltar which they had cause to regard as a natural inheritance.

SUDDEN RISE OF GERMAN COMPETITION.

But behold the great awakening! Across the channel a score of small kingdoms of like ancestry had been slowly preparing for the most astonishing things. In the throes of the Franco-Prussian war a great nation experienced a new birth, leading to such a series of material achievements as the world has never witnessed before. Within twelve years of the date of this new birth a Royal Commission from England, after a most careful study of the situation, reported that England had everything to fear and many things to learn from her new rival. The situation grows annually more acute and to-day England finds herself about to lose her position forever as the leading manufacturing and commercial nation of Europe. The explanation of this remarkable transition is deserving of the most careful study and it is of peculiar interest to the members of this Society. That an interior country like Germany, without a navy, and with little foreign commerce, could in a quarter of a century increase her manufacturing capacity ten-fold and make it equal to that of England;* increase her shipping twenty-fold, making it second to that of England; effectually establish a regular export trade with every country on the globe, and by at once cheapening products and improving their quality put herself in a position to hold these markets indefinitely; that all this could be accomplished in the face of open competition and in this age of universal publicity, is indeed marvelous and would alone prove that old methods have lost their potency and that something new has arisen under the sun.

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* See Mulhall's *Industries and Wealth of Nations*, 1896.

CAUSE OF GERMAN PROSPERITY.

When we seek an explanation of these wonderful achievements we find only a rational and provident application of means to ends, but on the most gigantic scale, and persevered in far more consistently than has ever before been even planned, to say nothing of execution. It is evident enough that no art or science can be known until it has been learned, and to learn most rapidly and thoroughly one must be taught. For the past forty years Germany has been systematically teaching her people in every kind of commercial and industrial employment. These people are no brighter, have no more receptive minds or more skillful hands than the people of the Anglo-Saxon races. There are in England to-day millions of men and women naturally as capable and as desirous of employment as these thrifty and toiling Germans, *but they are left without competent expert direction.*

We say Germany has a paternal government, and one entirely unsuited to the independent spirit of the Anglo-Saxon people, but if we allow ourselves to be blinded by this argument we make, I believe, a tremendous and fatal mistake. When industrial capacity rested wholly upon traditional and empirical knowledge and upon manual skill it was absolutely essential that artisans should obtain all this knowledge and skill as apprentices in the shops and mills as manual helpers and as unintelligent copyists. But since nearly all processes of the artisan have now a scientific and rational basis, and the work is done by machines which are the embodiment of the highest type of human reason and understanding, and since the machines require an almost equally intelligent oversight and direction to produce their largest output, and furthermore, since the new discoveries of science require continued changes in materials and methods to keep abreast of the times and to hold the market, and entirely new industries are daily established founded on some new discovery or invention, and since the demand no longer determines the supply but new and improved supplies are constantly creating their own demands in all lines of industry, *it is evident that the efficient direction of any industry to-day demands a very large amount of technical knowledge which can not be learned at the bench or in the shops.*

While self-education is always possible, the obstacles are commonly prohibitive, and at best the results are meager and unsatisfactory. There is no more costly luxury than an inventive but ignorant superintendent. Germany has seen this situation most clearly and it is her clear perception of this problem and her rational and thorough solution of it that has raised her industrially from poverty and obscurity to wealth and fame in the short period of a quarter of a century.

THE NEW CONDITIONS OF PRODUCTION.

Germany was the first to perceive that by the application of steam power to industrial production the capacity for such production by a single country is almost unlimited. Thus any one of the leading industrial nations could easily produce enough of the more readily transported products to supply the entire world, and the amount any one nation will succeed in supplying depends wholly on its relatively superior knowledge, and on its facilities for manufacture and sale. The material prosperity of any country in the immediate future, therefore, will be determined far more by the intelligent direction given to its industrial pursuits than by either its natural advantages in raw materials and transportation facilities, or on its past achievements in any particular direction. The constant cheapening of the cost of production of manufactured articles by science and invention dwarfs into insignificance the apparent advantages of geographical position. The practical obliteration of time and space by the speed and economy of modern transportation facilities has caused the earth to shrink and shrivel to dimensions far smaller, relatively, than those of the Roman Empire in its palmy days. It is a small matter to-day for a single firm to do business in every civilized country on the globe. With the helps which the telegraph, the type-writer, and the telephone have brought into every business office, one man does the work of a dozen, so that the mechanical increase of production applies to the business office as well as to the shop. In the meantime the common people the world over are approaching one type of manners and customs, their aesthetic tastes are developing and their wants are indefinitely multiplying. Here again the improved supply is creating the demand and the more this supply is made to conform to the growing refined and artistic tastes of the people, the greater becomes its demand. The highest artistic talents of the best industrial artists are in constant demand in Germany, designing new and attractive patterns of form and color and texture to meet this rapidly developing taste of the common people.* And it is the common people who must be considered in manufacturing. These compose the great bulk of society and fix the demand for the great staples of production.

THE GERMAN MONO-TECHNIC SCHOOLS.

Seeing, therefore, that the capacity for production is limited only by the intelligence and foresight of a people, and that there is a rapidly growing and prospectively unlimited demand for all kinds of artistically manufactured goods, Germany set to work some forty years ago to supply this demand by the intelligently directed labors of her own people. This had long been the home of classical and military learning, but it now became also the very center and head of technical and industrial education. The members of this Society are all quite familiar with her high-grade

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*The city of Berlin alone manufactures and sells in England over five million dollars worth of ladies' mantles annually! *Rep. of Tech. Instr. Com.* of Manchester, Eng., 1897, p. 7.

engineering schools, but we are not so familiar with her industrial schools. In fact we have commonly spoken of these with more or less indifference, calling them *trade-schools.* We have assumed that the difference between them and the engineering schools was one of kind, rather than quality or degree. As a result of some recent study of the leading industrial schools in Germany, I am inclined to question the justice of our position. Since the sciences of mathematics, of physics, of electricity, of chemistry, of mechanics, of steam engineering, and of the materials employed, enter so largely into all these school courses, they are in fact schools of applied science and they now pass in Germany under the very appropriate name of "Mono-Technic" schools.* Such schools are there found for all the leading industries of the empire, and there are many schools for the same industry. Thus there are in Germany thirteen schools devoted to the textile industries, each with its peculiar organization specifically adapted to the region in which it is placed. As little duplication as possible is practiced and when the same field is covered in two or more schools, variations in methods are introduced for the purpose of comparing results. The students entering these schools have first to complete the course of study in their secondary scientific schools (or say through the sophomore year of our engineering schools), and then the course of study in the mono-technic schools is three years, of

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*See *Report of the Technical Instruction Committee*, city of Manchester, England, 1897.

forty-five hours a week, on the successful completion of which certificates are granted.

The fine and costly buildings in which these schools are installed; their elaborate equipment, with all the needful chemical and physical laboratories, and all the machinery required to convert them into regular commercial factories; their large corps of trained teachers and the very small number of students admitted to take their full courses; the administrative care and oversight given to them, and their very small tuition fees, all serve to make the training given in them extraordinarily expensive to the state. Thus the textile schools of Crefield had last year only one hundred and eight regular day students in the weaving school and forty in the dyeing and finishing school. In the weaving school was the director with fifteen assistant lecturers and six other assistants; in the dyeing and finishing school there were the director and three assistant lecturers, a special chemist for dyeing and one for finishing, or a force of twenty-nine instructors for one hundred and forty-eight regular students. There were, however, irregular students in attendance on night and Sunday courses. The plant of this school included extended chemical and physical laboratories fully equipped, drawing rooms, lecture and testing rooms, chemical museum, library, and reading rooms. *The mechanical equipment was that of a complete weaving, dyeing, and finishing works for all the finer grades of cotton, linen, woolen, and silk goods.* Commercial work is done on a large scale, the students doing the work under the direction of the assistants. Specially difficult tasks in dyeing are here undertaken and successfully accomplished, and regular consignments of this character are made by some of the leading factories of the empire.

This school is only one of hundreds in Germany which are training up a class of men for the *direction* of all kinds of industrial works in which scientific knowledge is finding its embodiment and application. As a result of this training we find such great industries as the aniline and soda works at Ludwigshafen on the Rhine, which has grown from employing a total force in 1865 of thirty people, to employing five thousand men and over a hundred trained chemists in 1897; also the optical and electrical works of Schuckert & Co., of Nuremberg, which started on a very small scale in 1882 but which now employs over four thousand men besides a large scientific staff, and which had in 1897 unexecuted orders on hand aggregating $15,000,000. Three fourths of all the coloring matters and pharmaceutical products now produced from coal tar are made in Germany, their total annual products are this class aggregating $40,000,000. The earliest chemical discoveries of these products were made in England, but there was not sufficient knowledge of applied chemistry in that country to utilize the discoveries.* It is such examples as these, of which there are many, that indicate that Germany is reaping the fruits of the painstaking and far-seeing policy she has entered upon: and if other nations wish to share her prosperity they must act with a like wisdom and determination. The proof that Germany's remarkable industrial prosperity is traceable very largely to her educational methods* is not only granted by all foreigners who have investigated the matter, but it is so patent to the people themselves that they voluntarily unite to support schools for apprentices in their particular trades. Thus of the 248 mono-technic schools in Prussia alone which are so supported, the painters and decorators have 32, the shoemakers 9, the tailors 16, the bakers 20, the butchers 6, the smiths 26, and so on.

**Report of Technical Instruction Committee*, City of Manchester, England, 1897, p. 12.

Every trade has its own schools, aside from those supported by the state and by the municipalities. The artisans themselves see that systematic and scientific teaching entirely outclasses the old apprenticeship system, and these schools are constantly multiplying. In Saxony alone there are three of these mono-technic schools, besides ten schools of agriculture and forty of commerce. In the Grand Duchy of Hesse, with a million inhabitants, there are schools of agriculture and sculpture, nine schools for artisans, forty-three for industries, and eighty-two schools of design. The Grand Duchy of Baden with 1,600,000 inhabitants supports schools of industry, architecture, commerce, clock-making, cabinet work and music, with an annual expenditure of $280,000. In addition to these schools peripatetic teachers are employed to go from house to

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†See *English Consular Report* No. 2040, entitled *Trade in Germany*, April, 1898. Also the remarkable work of J. Scott Russell, entitled *Systematic Technical Education for the English People*, 1869.

house to instruct in embroidery and in the use of the sewing machine, the state selling these machines at a greatly reduced cost on condition that the purchaser shall explain its workings to her neighbors. In fact Germany, as viewed from without, would seem to be in the throes of a kind of educational fever. No doubt a large part of this educational work has been necessary as a result of the very backward condition of the common people along these lines, and to such an extent these methods could not find a place in this country; but aside and beyond these limits may we not see in the example of Germany the royal road to industrial prosperity? While the industrious character of the people; the military spirit which pervades all her industrial and commercial affairs, as well as the military and state departments; the absolute stability of her governmental policy and the fixedness of her currency and of her financial system; and the disposition to be satisfied with small wages and profits so long as these both rest on a sure and permanent footing—while all these certainly contribute largely to her present material prosperity, these same advantages are also held with her in common by some other countries which are not, however, sharing her present prosperity. The tremendous military budget of Germany cuts deeply into her productive profits, so that without this her commercial advancement would have been still more marked. It is not her army of soldiers, however, which other nations need to fear, *but her army of scientifically trained directors of industrial enter-*

prises and of the highly educated commercial agents at which they may well tremble.

THE COLLEGES OF COMMERCE.

For they not only educate the men who manufacture, but they are also beginning to look well to the training of the men who are to carry their goods to the ends of the earth and report the peculiar needs of every locality. Schools of commerce are being organized, modeled after those of France and Belgium, in which in addition to what is taught in our "commercial colleges" will be found a speaking and writing acquaintance with several foreign languages, especially English, Spanish, and French, if these have not already been acquired; political economy, industrial, tariff, and patent laws; railroading, shipping, postal and telegraph regulations; banking, exchange, coinage and national schemes of finance; industrial history, commercial geography, etc. A German national conference was held on this subject a year ago and a new system of commercial education is now being established all over the empire. Modern languages form a part of the elementary school training, especially English, so that the entering students in these schools are likely to be well equipped in this particular. With such material as these schools will turn out, their students coming from the better mercantile classes and having the manners and bearing of gentlemen, the large manufacturing and mercantile houses can establish branches in all the leading foreign countries, and with the system of foreign German

Library

banks which are even now found everywhere, the conditions are ripe for the ready and rapid sale of German products in all parts of the world.

From a remarkable publication by Mr. Frederick Emory, just issued from the Bureau of Foreign Commerce of our State Department, on the recent increase in our foreign trade and in reference to the necessity for the individual manufacturer and the merchant to study carefully the trade conditions in foreign countries, I quote:

"Nor is it with the relation of the different nations to one another that we are alone concerned. The industrial changes current within the territory of each obtain a new and much graver importance in their possible effect upon our nascent development as an exporter of manufactured goods. The conditions contributing to the rapid growth of manufacturers in recent years: the fiscal changes in Russia, India, and Japan, as well as in some of the Latin-American countries; the extraordinary impulse given to the industrial growth of the German Empire as a factor of international trade; the advance of Russia on similar lines: the rapid progress of the Siberian railroads toward an open port on the Yellow Sea; the efforts of Great Britain to meet the encroachments of other nations: the decline of the sugar industry in the West Indies as a result of the beet-sugar competition; the troubles of Spain with her colonies; the discovery of gold in Alaska and the adjacent territories in British Columbia; the tariff legislation of the United States, Canada, and other countries; all the phases of economic changes during the past year have an interest and importance for the individual operative in the United States which are greatly enhanced by the transformation now going on in our industrial life, converting us slowly but surely from a people absorbed with the internal development of a virgin continent into one of the great commercial powers of the world, with the international interests and responsibilities which such a position naturally implies."

Evidently, in order to keep abreast of all such changes, which are constantly going on the world over, a special class of highly trained men is required. And here, too, the supply of such a new and improved kind of clerical assistance would at once create its own demand. It would seem the time is now ripe in this country for the establishment of such schools. They are needed as much or more for the training of our foreign consuls, as for the commercial agents of our large business houses and industrial establishments.[*]

In France there are eleven of these high-grade colleges of commerce.[†]

The course of study is two years, with a preparatory year, all of thirty-three lecture hours a week. The following is a brief outline of the distribution of this time, the minimum age being sixteen years, which is predicated upon a preparation about equal to our college entrance requirements to which has been added in the preparatory year about all that is taught in our American so-called Commercial Colleges:

DISTRIBUTION OF TIME IN THE FRENCH COLLEGES OF COMMERCE.—(Time two years.)

Eleven hours per week to Commercial Methods and Transactions in what is called the commercial bureau.

Three hours to Commercial Geography.

One hour to the History of Commerce.

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[*] See an article by Senator White, on *Our Inadequate Consular Service* in *The Forum* for July, 1898.

[†] For a full description of these and also of those of Belgium, as well as a complete exposition and analysis of the entire system of English Technical Education, see *Proceedings of the International Congress on Technical Education*, held in London, June, 1897, under the auspices of the Society of Arts. See, also, Prof. James' *Report to the American Banker's Ass'n* on *The Education of Business Men in Europe.*

Two hours to a study of Commercial Products, involving the actual handling of the materials.

Two hours to Commercial Law, maritime and industrial.

One hour to Political Economy.

One hour to Type-writing.

Four hours to a speaking and writing knowledge of English.

Four hours to a speaking and writing knowledge of some other language; as German, Spanish, Italian, or Arabic.

Three hours to some special course in Chemistry, Transportation, Microscopy, Commercial Technology, or Stenography.

THE LESSONS FOR AMERICANS TO LEARN.

But you may say, what is all this to us? Have we not the finest system of public schools in the world? Have we not any number of Manual Training Schools and numerous Pratt and Armour Institutes? And, finally, have we not a great many engineering schools as good as the best, even in Germany? And have we not "Commercial Colleges" without number?

Suppose that I grant all this, may I not still say that the common schools give no special preparation for any kind of employment; that the manual training schools likewise fit for nothing in particular; that our engineering schools fit for very narrow lines of professional employment and commonly educate men away from the industrial pursuits rather than towards them; and as for our so-called commercial colleges, what do they teach beyond arithmetic, book-keeping, stenography, and type-writing? Where then does the specific scientific training for the manufacturing and commercial industries come in? I submit that it does not come in at all; that our factories and business houses are largely managed by men of little or no scientific training, who have learned their crafts in the traditional way; who are, however, of an inventive turn of mind and who read the trade journals. They are a great credit to the system that has produced them, and many of them have become self-educated into an excellent state of efficiency; but as a class they are far from the ideal directors of such business, and very far indeed from the standard already achieved in Germany. Their success can in most cases be attributed to the extraordinary conditions offered by a new and rapidly developing country rather than to any superior ability on their part. Our largest iron and steel industries and our metallurgical and electrical works are now well-directed by scientific men, but even these have not the properly trained agents to exploit their wares abroad.

Again you ask if we are not now the greatest manufacturing nation of the world, and are we not sending many of our manufactured products to all the countries of the old world? It is true that this is the case, and yet I am not very confident that this is a promise of that great material prosperity which this country should enjoy. It has been well said that *America* is but another name for *opportunity*. This is certainly true. Never before in the history of the world has man had such fabulous opportunities for material good as we have had given to us in this glorious land. Nowhere else on the face of the globe is there such a land. With a soil of exhaustless fertility if properly cultivated; with original forest resources sufficient to supply the world for centuries; with an infinite energy stored in our ample coal beds, and in our oil and gas deposits, which are almost co-extensive with our territorial limits; with the richest iron ores so plentiful and abundant as to make their value scarcely more than common rock or earth; with copper, lead, zinc, gold, and silver deposits in marvelous quantities; with a climate all that could be desired and nowhere equaled for agricultural purposes; and finally, but most of all, peopled by the most progressive races under the sun; with all these infinite opportunities, surely something should have been accomplished. And because much has been accomplished we are prone to attribute our unprecedented progress to our own superior wisdom, and so we are being consumed by our own egotism. As a partial correction to this tendency let us glance for a moment at some of the unworthy and foolish things we have done, in order to bring ourselves into a more teachable mental attitude.

We have exhausted a large portion of our lands by spendthrift and improvident agricultural methods, and have moved on to the next new country to repeat the process until we have reached our uttermost bounds and have been turned back by the inhospitable mountains and desert plains; we have squandered our forest resources and are even now seeking timber supplies from our northern neighbors; we have wasted our natural gas supplies in a most foolish and prodigal manner: we have enslaved an inferior race and then quarreled over them at the cost of half a million of lives, and thousands of millions of dollars; we have foolishly trifled with our finances and with our civil and consular services, in a way to bring upon us the contempt and loss of confidence of all honest and intelligent nations; we have built railroads enough to girdle the globe many times, and have persuaded foreign capitalists to loan money on them to many times their cost and to far beyond their productive capacity to pay; we have allowed our shipping to dwindle and die and are sending out all our exports and receiving our imports in foreign vessels, and by such lines as suit their own interests; we have given away our municipal franchises to favorites, or for pelf, and so put upon our people burdens of taxation which should have been paid by the profits which now find their way to the coffers of our multi-millionaires, of which all our large cities are able to boast; we have allowed our voters to be corrupted by our special legislation, by our wholesale pension lists, and by our covert bribery at national elections, until the feeling of patriotism with all its altruistic accompaniments has largely given place to the party query, "what is there in it for me?" We have acknowledged our inability to govern our large cities, and they are turned over to hungry hordes of self-seeking and dishonest ward-committeemen, who serve only the party boss; even in the face of a foreign foe we have subordinated military to political rule, trusting in the weakness and greater blundering on the part of our enemy rather than to a studied fitness of men and means for the successful prosecution of a righteous war: in short, are we not running the race of the prodigal son, and should we not now come to ourselves and ask if there are not better methods of administering our heritage to be learned in our father's, or, as I am insisting to-day, in our grandfather's house? Any spendthrift appears to prosper as long as the money holds out: our inheritance from nature was so bountiful it is holding out well; but we are spending and wasting it as rapidly as possible, and we are beginning to find ourselves cramped to maintain our unwise and extravagant courses. In fact, for the past five years, we have suffered greatly and have not known what was the cause of our distress. Our manufacturing industries have been greatly depressed, while those of foreign countries have been experiencing a period of unwonted prosperity. Six million of our voters have said, in effect, our distress is the direct result of our neglect of the worship of their silver idol and of worshiping instead a golden calf. Various quacks have prescribed for our debility, but in my humble opinion the seat of the trouble has been in the head. We are reaping the legitimate fruits of our own foolish sowing. We sowed the wind and have reaped a whirlwind. We have ignored and scouted all the established laws of material prosperity, saying they did not apply to this country, and after five years of punishment for our sins of ignorance we are still shutting our eyes to the plain teachings of our sorry experience.

But this address was not intended to cover the whole category of national ills: it was to be limited to the prime essential conditions of our material prosperity in the immediate future. In the first making of a country the industrial demands are so great that the ordinary laws of trade and commerce do not apply: but now our country is fairly well developed, and we are practically on a par with the countries of Europe so far as our manufacturing industries are concerned. We can supply far more than our own demands, and the profitable marketing of this surplus will soon mark the difference between prosperity and adversity. We are now relying largely upon our boasted ingenuity, and of this we well may boast; but in the future nearly all the profitable inventions will involve a large amount of scientific knowledge on the part of the inventor. In fact, our technical schools claim to train men to become inventors, and this is indeed true. Inventors, hereafter, will be made, not born; the born but untrained inventor is daily becoming more dangerous and will soon be avoided as a calamity.

CONCLUSION.

The most essential condition of our future material prosperity, therefore, is as I conceive it, *a specific scientific training for the directors of each and every kind of manufacturing and commercial activity.* This is the burden of my address: the imperial and paternal government of Germany has worked out this problem to a most fruitful issue, but probably no other country could duplicate it. England has been trying for ten years to do so, but with very poor success; instead of highly educating a few leaders and directors of industry and commerce, they are vainly trying, at an expense of some five million dollars a year, to raise their entire class of apprentices and clerks by a wholesale system of shallow night-school instruction. Apparently a duplication of the imperial German system is not to be thought of in this union of forty-five independent states. The great question for us to solve is how to obtain a corresponding specific training for our industrial officials. The problem is a difficult one; to expect that our American municipalities would engage in such a rational expenditure of funds is beyond our credulity or hope. Our state legislatures are not likely to realize this need so fully as to inaugurate and to consistently support a series of such schools. The National Government now pays out of the United States treasury directly to the several state agricultural colleges one million dollars a year, and I fear without adequate returns. If this amount or more could be annually devoted to paying the salaries and superintending the instruction in a properly administered series of mono-technic schools would not the primary purpose of these schools be more fully met? This purpose is defined in the original act of Congress in 1862, to be "to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." The first cost of any new buildings and equipment required could certainly be secured by local state, municipal, or voluntary aid. To insure a proper coordination, rather than duplication, of their work. these schools should be controlled by boards, in all of which the United States government should be represented.

It is true that some beginnings have been made toward the inauguration of such high grade industrial and commercial schools as are here contemplated. At the State University of Ohio, in conjunction with the National Brick Manufacturers' Association, a special course of study has been put in operation covering the clay industries, but not including ceramics and cement manufacture. In the city of Philadelphia we have a school of industrial art, started under private auspices but now under the patronage of the state, which is said to rank with the best industrial schools abroad, especially in its textile department. At the Universities of Pennsylvania and Chicago the studies in political and social science have been given a commercial application, and a few of our largest cities are also making a start toward the establishment of commercial high schools. It is well known that our mechanical, electrical and mining schools fairly cover the theory and some laboratory practice of our various mechanical, electrical, and metallurgical works, and this schooling is usually supplemented by tours of inspection to large typical works. So far as the graduates of these schools engage in the manufacturing industries they serve the purposes herein contemplated, but they are entirely inadequate to answer the general demands of a manufacturing and commercial people, and it is evident that we have not yet set ourselves earnestly to solve this problem.

It is probable that our organized commercial bodies offer the most favorable auspices for the inauguration of these mono-technic and high-grade commercial schools. The problem is, however, not without its difficulties, and before anything is done, or even recommended, the whole question should be examined and reported upon by a joint commission of educators, manufacturers, and business men appointed preferably by the national government. Our government has already made a beginning in this direction. Seven years ago an appropriation of five thousand dollars was made by Congress, to be spent by the Labor Commissioner, in reporting upon the methods of technical education practiced at home and abroad. Mr. Wright brought out a very full report on this subject in 1893, which may still be studied with profit. As this kind of education is so foreign to the spirit and methods of all forms of general or culture education it would seem to demand also a separate bureau for its administration, and this we should have to have if anything of consequence is accomplished.

And now, as a conclusion of the whole matter, should not this Society take the initiative in these movements? I believe it should, and I believe the future material prosperity of this country is very largely dependent on how these problems are solved. Let us remember that we can no longer judge of the future by the past; to-day both the successful manufacture and the sale of goods are reduced to exact sciences. Old things are done away and all things have become new. Let us see to it that our ship of state shall be guided by the lights which are now so successfully leading others through the channels of progress, rather than to continue to steer by the vanishing lights of a tortuous past which may eventually land us on the sandy banks of delusion and improvidence.

THE CLASS ROOM AND THE LABORATORY IN THEIR MUTUAL ADJUSTMENT TO THE END OF THE MOST EFFICIENT INSTRUCTION.

BY GAETANO LANZA.

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Before discussing this subject, it seems to me that we need to consider what it is that we wish to accomplish by giving the student an engineering education.

Naturally we wish, as far as any education can accomplish it, to fit him, as thoroughly as possible, to meet and grapple successfully with the duties of his profession, including the problems of a technical nature which he will be liable to meet in the practice of his profession, and also the responsibilities that he will have to assume as an engineer and as a man.

In order to accomplish the last he must be given a broad and liberal education, and hence we must not neglect the sides of pure science and literature in laying out the course.

Having called attention, however, to this matter I shall not refer to it farther, but confine myself to the professional side of engineering both as represented by the class room work and the laboratory work.

To the engineer, a knowledge of scientific principles and of the experience of the past is all-important;

and to impart this knowledge is the special function of the school; for no school can relieve the student from the necessity of acquiring his own experience after he leaves the school and enters upon the duties of his profession.

Indeed a man who is not familiar with the scientific principles which concern his work is not a safe man to be trusted with responsibility, for scientific principles are merely the laws of nature, as far as known, as shown by the experience of the past.

The fact is, that to impart to the student a thorough mastery of the scientific principles, far outweighs in importance anything else that can be done for him; and it is a great mistake to neglect this in order to give him a more thorough drill in those processes that will chiefly engage his attention when he first goes into practical work; as, for instance, to give him such a thorough drill in drawing as to make him an elegant draughtsman; such a thorough drill in surveying as to make him an expert surveyor, or such a thorough drill in shop work as to make him a finished machinist.

Greater skill in such processes can far more easily be acquired after he enters upon practical work than can scientific principles; and if the latter are sacrificed to the former on account of the small advantage gained at the start, the consequences will probably pursue the young man throughout his professional life, and will render it much more difficult, and generally impossible, for him to compete with others in whose education the mistake referred to has not been made.

In view of all the above, it seems to me that it must be evident to any one engaged in the teaching of engineering, that the class room work is of the first importance, and forms the basis of the course, and that the laboratory work, in order to serve its purpose, must be based upon, and be thoroughly coordinated with, the class room work, which should always precede it, and to which it should serve as an aid.

Nevertheless, the engineering courses of our schools would not be able to impart to the students a familiarity with scientific principles at all adequate to their needs were it not for the aid furnished by the engineering and other laboratories.

Indeed, were it not for the introduction of laboratory work in our engineering schools, all their modern development and the high character of their work in engineering education would have been an impossibility; for, the laboratory work has not merely served to illustrate and elucidate that of the class room, but it has also reacted upon it, and, by submitting it to the test of experiment, has caused the class room work to be so modified as to accord with the facts; and therefore the laboratory work has produced an enormous development in the class room work itself.

Indeed the general appreciation of the importance of engineering laboratory work is shown by the fact that, since its first introduction into a few of the larger engineering schools about twenty-five years ago, it has had such a rapid development that, to-day, there is hardly an engineering school in the United States but has introduced laboratory work into its course: and its importance is being more and more recognized in England and on the continent of Europe.

The functions of the engineering laboratory are, partly to emphasize and illustrate the work of the class room, partly to drill the students in performing, carefully and accurately, such experimental engineering work as they are liable to be called upon to perform in the practice of their professions, and partly to teach them to carry on experimental investigation.

In order to fulfill the first of these functions there should be the most intimate relation between the two, so that the work in the laboratory shall make clearer to the student what he has learned in the class room, and that he shall find, when he is to work up the results of his tests in the laboratory, that he has already learned in the class room the principles which enable him to do so; and he should be made to think for himself, and to use these principles in working up results.

Any organization which does not tend to preserve the most intimate relation between the class room and the laboratory work is not for the best interests of the students and should not exist. Other grave disadvantages of any such scheme are as follows:

If the laboratory is not made dependent upon what the students have previously learned in the class room, a great deal of time will be necessarily consumed in explaining the apparatus used in the tests, the objects sought in making the tests, the reason for the special observations taken, and the manner of working up results; whereas, if the laboratory work is properly coordinated with and made to follow the corresponding class room work, the amount of time required for the above stated objects will be very small.

Again, if the student has not already had the corresponding class room work, before performing the experiments, he has not had the preparation necessary to make him fit to perform the tests, or to derive from their performance the benefit that he should derive from the tests; also, in order to enable him to work up the results the instructor will have to give a special explanation to the students, as to how to work up the results of each separate kind of test, giving him rules for working them up empirically, instead of requiring him to find the solution for himself in the light of what he has studied in the class room; and thus the laboratory would become a place for empiricism instead of a place for thought.

In order to make the laboratory work of value the greatest care, accuracy, and thoroughness should be insisted on in all parts; no careless work should be tolerated; the student should be required to make all the calculations necessary to work up the results of all the tests in which he takes part, and to hand in his results in a short time (as one week) and if he has made mistakes in his work he should be required to do it over and hand it in again.

If he is trained to perform accurate and thorough work, he can easily adapt himself to perform rough-and-ready work as the occasion may require, but a man who has only performed rough and inaccurate work can not even be trusted to discriminate between the portions of the work where accuracy is an absolute necessity, and those where it is of less importance.

By way of conclusion we may say that the great impetus given to engineering laboratory work, in recent years, marks one of the most important developments in engineering education, not only by teaching the student to perform such work with his own hands, and to plan the experiments in the proper way; not only to teach him to observe the facts as shown by properly conducted experiments, to judge of the correctness of the experiments themselves, and thus to derive instruction at the feet of Nature; not only to organize and make investigations properly, but also to test constantly the theories which he learns (these theories being merely the conclusions drawn thus far by others from past experiments) and to draw his own conclusions, not merely in individual instances, but also in regard to truths of more general application, in the light of all the evidence furnished by the facts of nature, whether observed by himself or by others, provided only the observations have been correctly made.

All the above is accomplished, if the laboratory work is properly conducted, and if its relation to the class room work is such as it should be; but if it is improperly conducted, and if it is not properly coordinated with the class room work, the laboratory work itself loses the greater part of its value.

DISCUSSION.

Professor J. B. Johnson said he thought that Professor Lanza had outlined the proper spirit of laboratory work; and he wished to reinforce what the author had said toward the close of his paper as to the great significance of the recent growth of laboratory work in connection with engineering schools. The speaker said that nowhere else could it be found to the same extent as in this country; and he believed that those who have experienced its advantages would be united in insisting that engineering science, that is, applied science, can not be taught without it. Applied science can not be taught with a blackboard and a piece of chalk. Others, who have limited themselves to the blackboard method of teaching, would say, "How would you produce such a man as Rankine? He was not produced in the laboratories; yet those that do a great deal of work in laboratories think a great deal of such men." The speaker thought the answer should be that such a case is the rare exception, and its rareness proves the rule; and the rule is that ordinary boys and men can be taught applied science only by the actual application of scientific principles. While they may not be applied on a large scale for the purposes of instruction, as in building bridges, railroads, etc., yet in the limited applications that they can make in the laboratories they can do much work involving the scientific principles that they have studied. The speaker further said that he thought the Society was constantly emphasizing and should emphasize its belief that no institution in America to-day should be willing to hold to the method of teaching engineering science without adequate testing laboratories, and that it should be left to their own consciences as to the interpretation of the word "adequate."

PROFESSOR FLATHER asked whether, in Professor Lanza's practice, the experiments, which he suggested should be worked up in a week, are worked up as a part of the laboratory exercises, in the laboratory period, or outside, in the student's own time.

PROFESSOR LANZA replied that the greater part were generally worked up outside.

PROFESSOR HIBBARD took exception to the statement that laboratory work should be done with extreme accuracy and that speed could be acquired naturally and intuitively without instruction on that particular head. He said that the student is being prepared for commercial work and not for the work of the laboratory after leaving the technical school; and therefore he believed that instruction should be given in the laboratories in the quick methods that are employed in commercial work, and that the student, when he leaves the school, should know how to perform experimental work, not only with great accuracy, but also with rapidity.

PROFESSOR FLETCHER said that, touching on the last point, everyone is willing to grant that in the drawing room students should not be expected to become expert draughtsmen, but should acquire such a reasonable facility and degree of rapidity in work as would make them at once available; and, in the same way, if the field work of the civil engineers is called part of the laboratory work in applied science, a reasonable facility in the use of instruments should be aimed at. After a sufficient course has been given in the measurement of angles, processes of leveling, etc., additional practice should be given to allow the young men to acquire reasonable facility of action, so that when in the exigencies of practice they are called upon to assume responsibility, they shall not be considered utterly useless because they are so slow in mental processes and execution as to be immediately considered quite inefficient and unable to earn adequate compensation.

Professor Swain remarked, as bearing upon what Professor Johnson had said in reference to the paper, that whereas thirty years ago we had no laboratories, since the "new education" has come in almost everything is now being taught by what we may term the laboratory method—even history and literature. The danger now is that we shall go too far in the other direction; and, in fact, it is just as certain that we shall go too far in the other direction as it is that the pendulum will swing past the lowest point, or that stocks will sell above their intrinsic value in a "boom" time. From much that the speaker had heard in regard to some testing laboratories, he thought that there is danger of going too far in making tests that will subordinate judgment to the results of testing; in other words, that the engineer might insensibly get into the habit of using the results of test, rather than of exercising his judgment. In any case in practice the conditions are generally different from those in a testing laboratory; and the most important thing is for the engineer to learn to exercise his judgment and to think, rather than to rely too much on testing.

PROFESSOR HOLLIS said that he thought the engineering schools in this country have gone too far in laboratory work. He believed in laboratory work, but he knew of good engineers that have been produced without laboratories. There are two classes of young men who go to the schools: those who are engineers by nature, and those into whom engineering must be driven. For the second class, engineering laboratories are necessary, and certain rules are necessary; and it is with that class, by far the larger, that we have to deal. The speaker referred to his experience in teaching during the past five years; there was a moderate amount of laboratory work connected with it, and men that had come out of the school had done very good work after graduation. In connection with the struggle that the country had just gone through, the speaker said that he was tempted to cite the case of the Commander-in-Chief of the North Atlantic Squadron, whose education had been chiefly in physics, and yet he was successful in the practice of his profession. For himself, the speaker said he preferred the physical laboratory to that of engineering; he was impressed with the thought that young men must learn their engineering after they leave school, and that we must trust a great deal to that. A young man in a law or a medical school gets what has been erroneously termed "a culture" education, and then spends three or four years in learning his profession. It seemed to the speaker that that is just what the engineer must do; his three years must be spent in the shop or in the field. One of the great dangers with the schools all through the country is that they graduate men under the impression that they are engineers. He had been told by a number of people who employed engineers that they would rather have a young man well grounded in applied mechanics than one who had had a great deal of laboratory work. The speaker himself would not go so far as that, because he believed in a certain amount of laboratory work; but it seemed to him that theories are not so important as the proper men to teach students. A man of good judgment will get good results in dealing with students.

PROFESSOR LANZA spoke with reference to some of the remarks that had been made in the discussion. As to the importance of students being able to adapt themselves quickly to practical work, it had been his experience that the student who has been taught to work accurately, can readily adapt himself to more rough-and-ready work when that is required; whereas the one who has not been so drilled can never be relied upon to perform his work with the degree of accuracy necessary to render the results of value. The speaker's experience convinced him that the best thing to do is to teach the young men that their work should be done accurately, and that experimental work that is not accurately done is comparatively useless. As to speed in drawing, etc., the men should of course acquire sufficient experience in the school to enable them to make themselves of value on leaving.

The speaker said that the idea that engineers could be produced just as well without the laboratory is not true. Indeed the world would not progress, if we only gave to our children the opportunities that our grandfathers had: hence we should furnish to them the best facilities available, and start them with the world as it is *to-day*.

NOTE ON THE ORGANIZATION OF AN ELECTRICAL ENGINEERING LABORATORY.

BY HAROLD B. SMITH,

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The large number of electrical engineering laboratories that have been equipped during the past ten or fifteen years in connection with the educational institutions, government bureaus, and manufacturing establishments of this and other countries demonstrates conclusively the widespread approval of laboratory methods in electrical engineering work. The large sums of money appropriated in many instances give some indication of the importance of the equipment of such laboratories.

Local conditions as to class and number of students in the laboratory, character of work undertaken, relations to the other departments of an institution, the organization of the electrical engineering department itself, and the amount of money available for development and maintenance of the laboratory, must necessarily control its organization to a great extent; but there are certain details of importance which can be incorporated in nearly all laboratory equipments to advantage, and this paper has to do with some of these questions of detail, rather than with the broader questions of pedagogy on which these details must depend.

These broader questions of general fundamental principle have been thoroughly discussed in papers before this Society and elsewhere during the past five years, and there seems to be more occasion at the present time for a consideration of details of organization.

An electrical engineering laboratory may be organized in as many ways as there are laboratories: and the best method of development is probably an open question as yet. It is certain that no one general plan can be followed under all conditions without positive loss in many cases. A research laboratory must necessarily be equipped quite differently from one designed for the accommodation of undergraduate students in routine laboratory work: and while both kinds of work must be provided for in most laboratories, it is seldom that the expense involved in the entire separation of the two classes of work can be permitted, nor is it desirable to do so except in a very few instances.

It is held by many that the undergraduate instruction in an electrical engineering laboratory should consist of a comparatively few experiments, in which the student is thrown entirely upon his own resources. even to the extent of creating his own apparatus. for the purpose of developing in him the qualities of judgment, common sense. originality. and independence. While the cultivation of these qualities is most highly desirable. it is believed by the writer that the undergraduate laboratory course should be conducted primarily, though by no means exclusively. for other purposes. and that the proper place for special training of this nature is to be found in the preparation of the undergraduate thesis and in post-graduate study. The undergraduate laboratory course should be so planned as to give the student the greatest possible familiarity with generally approved methods, apparatus, and principles. A course giving general and special information of this character is essential before the student can do original work economically, and all devices are of value which contribute to a shortening of the length of time required for gaining this knowledge. It is believed that in the end equal, and usually better, results can be secured for undergraduate students by following a plan intermediate between the method just criticised and the other equally radical and most thoroughly undesirable method of providing a series of set exercises with apparatus ready for manipulation so that the student races through his experiment without the possibility of encountering difficulties or understanding the significance of his work.

It is important that the student should set up and adjust all apparatus and make all electrical connections for himself without the assistance of an instructor; but it is not necessary that he should always be given an ammeter or voltmeter that is out of calibration in order that he learn the importance of a reliable instrument and become an expert in adjusting and calibrating instruments. Two or three experiences of this sort, in an extended course, are sufficient to impress these points on the mind of an average student, and more would be a waste of time. The setting up and operating of a single dynamo or motor which has been taken apart, some common defect introduced, and all connections broken, is a sufficient lesson in most cases: and when the student has occasion to use a dynamo or motor at other times he should be provided with one that is in good condition and be required to maintain it properly for its work.

In order that he may be able to make all connections for himself without loss of time and without encumbering the laboratory with a mass of temporary and unsightly wiring, which is always in the way of other work, a carefully planned system of permanent wiring should be installed, connecting all apparatus and parts of the laboratory to properly and systematically labelled terminals on convenient switchboards. These terminals may be connected by the student with flexible cables and then disconnected by him at the end of an experiment. It has been the experience of the writer that, in this way, the confusion of temporary wiring is avoided and so great a flexibility of working is secured that, for a given equipment, a greater number of students may be handled in a wider variety of work with less unprofitable expenditure of time than by any other method with which he is acquainted. All apparatus may be protected by fuses or automatic cutouts so that there is little danger to the apparatus when connected in this way by inexperienced students working by themselves. In fact, a few short circuits, because of faulty connections, have a most wholesome effect upon the student and the instructor should not prevent such connection when he may see one about to be made. In a laboratory handling a large number of students, not more than ten to twenty pounds of brass terminals will be destroyed in this way each year, and their cost is money well invested.

Circuits carrying not over 250 volts should be used in this way when students first enter the laboratory; but with two months' experience in the laboratory, it is safe to allow the use of 500 volt direct current circuits and after six months, 1,000 volt alternate current circuits. After an experience of several years with this system of working, it has been found that each year two or three men serve as valuable object lessons to the remainder with slight burns on the hands from the 500 volt circuit.

If it is granted that the student must have as wide a knowledge of experimental methods and apparatus commonly used and generally approved as may be secured in a given time with a given equipment, before undertaking the development of independent experimental methods of his own, it is believed that a laboratory arranged as proposed will reduce to a minimum all time and labor spent in unprofitable moving of machines and apparatus, temporary wiring, repeated calibration, and general preparation of a purely manual character which has no value as training in electrical engineering. This leaves time for the performance of a wider range and a greater number of experiments or for the earlier taking up of research work.

When research work is undertaken, it is found that a laboratory arranged in this way possesses just the flexibility demanded for such work and that all the facilities of the entire equipment that may be desired for a given piece of work may be concentrated upon it with the least expenditure of unprofitable labor.

Special pieces of apparatus developed in connection with research or routine work should be united with and made a part of the same general system, so that, in the progress of the work immediately at hand or in work that may be taken up later, all special apparatus is at once available and often of great service for purposes that were not even remotely contemplated at the time of its development.

The various subdivisions of an electrical laboratory equipment for the purposes of direct current, alternate current, testing of materials, standardization, electro-chemical and other work, may be located preferably in separate rooms, each room with its own switchboard and interconnecting lines from switchboard to switchboard; these rooms should be grouped conveniently and should form units of a systematically arranged whole.

It is important that a few generators of considerable capacity, capable of furnishing an ample supply of 125 volt and 550 volt direct current and single and polyphase alternating current, should be arranged closely in accordance with station practice, for the general supply of current and for purposes of instruction. This may be secured most conveniently in a power house containing steam, gas, or hydraulic equipment, used in common with other departments and connected by suitable lines with the other laboratories and buildings for the distribution of current for lighting and power purposes. In fact, such a distributing and transmission system may in itself form a most valuable educational feature of the equipment.

Laboratories equipped in accordance with the method outlined accommodate themselves without difficulty to extended development, wide range of work, and unusual temporary conditions of working, because of their systematic arrangement and flexibility—principles which depend upon details for their achievement.

SOME PHASES OF ENGINEERING EDUCATION IN THE SOUTH.

BY JOHN J. WILMORE.

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Engineering education in the South has troubles of its own. It also shares some of the troubles that are felt in other sections. The peculiar social and industrial conditions that existed before the Civil War are now pretty well understood. The sharply drawn class distinctions tended to destroy ambition, in both the higher and the lower classes of the white people. As expressed by Professor Edwin A. Alderman, of the University of North Carolina, "This order was a system of contrasts and lights and shadows. It produced neither wealth nor letters. It dishonored labor, arrested immigration, minimized invention, unified industry, and exalted caste."

As if to further emphasize the contradictory elements in the make-up of this people, we find the earliest efforts in the direction of scientific and technical education were made by Southern men. As early as 1818, Thomas Jefferson, in enumerating the objects of higher education, included among them "to harmonize and promote the interests of agriculture, manufactures, and commerce" and "to enlighten our youth with mathematical and physical sciences, which advance the arts, and administer to the health, the subsistence, and comforts of human life."

The same man, in a report to the Legislature of Virginia, the same year, outlining a course of study to be given in the University of Virginia, the organization of which he was striving to hasten, proposed to start the University with ten departments, four of which were to be purely scientific. In a letter to a friend on the same subject, he suggested what he called "a school of technical philosophy" in which should be taught "the sciences of geometry, mechanics, statics, hydrostatics, hydraulics, hydromechanics, navigation, astronomy, geography, optics, pneumatics, acoustics, physics, chemistry, natural history, botany, mineralogy, and pharmacy;" and further, "the use of tools, too, in the manual arts is worthy of encouragement, by facilitating to such as choose it an admission into the neighboring workshops."

Thus we see that four score years ago the Sage of Monticello had grasped all the essential elements of the modern technical college, although at that time he was not able to have his ideas made effective in the organization of the University so near to his heart.

Another fact of some historical interest is that probably the first manual training school in the United States was organized and conducted by the Baptist Church in Georgia. In the year 1833, at a place known as Penfield, in the State of Georgia, with Mr. B. M. Sanders as principal, Mercer Institute, now known as Mercer University, was organized. The students were required to work two hours a day except Saturdays. A student at that time, writing many years afterward, feelingly says, "the work was on the farm. There was also a sort of mechanical department. A preacher 30 years old, parrot-toed, a carpenter—he bossed it. For a long time I worked at the whipsaw."

The year following, Wake Forest Institute, now Wake Forest University in North Carolina, another Baptist institution, opened its doors offering a similar curriculum of classics, theology, and farm work. No effort seems to have been made to make the manual feature instructive. It was apparently introduced under the "apprehension that much learning might tend to seduce them (the students) from a just estimate of frugality, industry, economy, and the performance or the superintendence of manual work." The idea was excellently expressed by a "well-to-do old farmer who, when asked if he intended to send his boys to college, answered: 'No, that I ain't; seem to me the mainest things them college boys learn, is to chaw and smoke seegars, talk dictionary words, git above work, and be imp'dent to old people.' "

The conditions at the end of the Civil War have been often described. The paralysis of all industrial operations due to the changed labor conditions and the demoralization of all civil and judicial functions during the "carpet bag" *régime*, delayed the acceptance of the Government and grant for the establishment of colleges of agriculture and mechanic arts, in nearly all the Southern States. And even after it had been accepted, the early progress of the institutions was retarded by prejudice. To the old-time Southerner, education meant literature and classics and did not mean any thing else. The ideals of a generation before had been lost. In some cases the technical department was a makeshift and only intended to hold the appropriation, which was mainly used for other departments. Within the last ten or twelve years, this feeling has been rapidly disappearing and the money is now used as conscientiously as in any other institutions. The rapid development of the electrical, cotton, and iron industries has opened the eyes of the people to the necessity for engineering training.

The Southerner being a natural politician, it has unfortunately been impossible to keep politics out of many of the Southern colleges. This is in any case a disaster to be deplored; but when the college gets on the losing side of the political game it is usually fatal to the progress and well-being of the institution. Some Southern colleges have suffered in this way.

The problem of entrance requirements and preparatory training is a difficult one. Considered from the standpoint of the funds available, the condition of common school and secondary education in the South is good, but considered from the standpoint of a preparation for college, it is far from satisfactory. It is in most cases impracticable for a college to extend its course to cover five years, and this is what occurs when an extensive preparatory department is maintained. It then remains to place the entrance requirements for freshman class to meet the average attainments of the students of college age who apply for admission. Raising the age of admission will do more harm than good, because the student would probably leave school at the same time in either case; and if not old enough to enter college, he would go elsewhere, or work a year or two, and would be less able to stand examinations than when he was fresh from school. In many cases, so far as the personal experience of the writer goes, this poor preparation is not so much a lack of teaching as a lack of training. Students who can perhaps solve with ease quite difficult problems in algebra or trigonometry, will be utterly helpless if asked the velocity of a belt running over a pulley one foot in diameter making three hundred revolutions per minute, or the piston speed of a locomotive having five-foot drivers, a two-foot stroke, and running thirty miles per hour.

The arrangement of a satisfactory course in engineering is sometimes beset by difficulties. In the institution with which the writer is connected, a student entering the freshman class to take the engineering course is required to take four years of English, one year of agriculture, one and one half years of history, one half year of botany, one year of physiology, one year of chemistry, one year of geology, one half year of astronomy, and four years of military tactics (all three-hour subjects except astronomy and geology, which are two hours per week). All these, with mathematics, physics, and the engineering studies, constitute the course. It will be evident that in order to give anything approaching a satisfactory engineering course the work must be presented in its most digestible form. Fundamental principles must first be given, and then as many of the various applications of these principles as the time available will permit.

Each institution has slightly different conditions to meet, and care should be taken in selecting these applications just mentioned in order that they may cover as fully as possible the line of work that the student will probably enter after leaving college. As an illustration of this point, the majority of the students with whom the writer has come in contact, have gone into street railway, lighting, or cotton mill power plants. For this work it has been considered more important that a man should know how to set up, inspect, adjust, and operate a steam engine than to know all of the refinements of its design. A course of designing is given, but it is not intended to cover more than the general outlines. A student should be given some ideas of practical conditions. It is important that he be familiar with ideal conditions, but equally important to know their limitations. For example, he should be made to understand that, notwithstanding the fact that a compound condensing engine uses much less water per horse power per hour, it may still be economy in many cases to install a simple noncondensing engine. In other words, we should strive to educate the judgment and discrimination as well as the analytical powers, for the success of an engineer depends largely on the correctness of his judgment.

A chronic ailment that affects all the colleges represented in this Society, is lack of funds. It is a universal complaint, and the worst feature is that it does not yield readily to the "faith cure,"—about the only remedy offered many of us for its treatment. It seems also, that a warm climate is especially favorable for the development of this malady in its most malignant type, so that we of the South are the extreme sufferers. The presence of "the brother in black" in such large numbers renders it necessary to maintain separate institutions for the two races, and for this reason the funds must be divided. Thus an income that might fairly support one institution is insufficient for two.

With one or two exceptions, no Southern technical college for the white race has received a substantial donation or benefaction in the way of endowment of chairs, departments, scholarships, or the erection or equipment of buildings. This is true, perhaps not because of lack of interest so much as lack of ability. The men who conduct industrial enterprises and who would be expected to be interested in the developement of engineering education, are usually little more than the agents of capitalists resident elsewhere, and who are only intent on getting the largest possible income from their investment. There are few Southern men who could be called wealthy as the term is understood in the North, and apparently none who are benevolently inclined.

The average fees,—tuition, laboratory, and incidental,—are lower in Southern than in Northern colleges. Few of the former charge any tuition or laboratory fees, while most of the latter charge both. Complete statistics to show the exact standing were not obtainable, but sufficient figures were found to fully substantiate the statement.

The legislatures of the Southern States show little disposition to assist technical education. It is true that they have not the means of the wealthier States further north, but with the proper inclination, much more could be done than has been done. In many of the Southern States, as in some of the Northern, the sale of the public lands given the States by the Government in the Act of 1862, was badly managed and the endowment fund greatly reduced thereby.

These obstacles, however, have seemed only to inspire greater enthusiasm in the workers; and where the conditions have been at all favorable, the work accomplished and the stand taken is very gratifying. For the purpose of comparison, nine colleges in the South and an equal number in the North were selected, care being taken to choose fairly representative institutions, and from their statistics some average results were computed. These results are as follows:

	NORTHERN COLLEGES	SOUTHERN COLLEGES	PER CENT IN FAVOR OF NORTH.
Average income per student.	$242	$172	40.7
Average number of students per instructor	10.7	12	10.8
Average number of volumes in library.................	41,307	11,420	261
Average value of library and scientific apparatus.................	$211,375	$41,587	408

The maximum income per student is $440.00 and the minimum $64.00. The maximum number of students per instructor is 15.6 and the minimum 6.2. These are from the statistics for the year 1896–97, except for the value of library and scientific apparatus, which are values given for the year 1895–96. The figures being based on total attendance and total income do not, of course, give any exact information in regard to the engineering departments. Neither is it expected that the value of library and scientific apparatus is an exact index of the value of the engineering equipment. But it is believed that any discrepancy that may exist in this direction would, if corrected, make the percentage still more favorable for the North, because of the fact that many of the Southern colleges have but recently introduced engineering courses and have a comparatively small engineering equipment, while they are fairly well equipped in chemistry, physics, and other sciences. The figures are significant in a broad sense and serve to give, in some measure, an idea of the average conditions.

With the hope that they may prove of general interest, the writer ventures to submit some statements more in detail, based upon personal experience. The department of mechanical engineering in the Alabama Polytechnic Institute is provided with a wood shop, a blacksmith shop, a foundry, a machine shop, a laboratory for advanced work, drawing-room, and lecture room, having a total floor space of about 12,000 square feet and an equipment that cost about $20,000. The professor and four assistants give an aggregate of one hundred actual class hours per week and handle about two hundred students. All students entering freshman or sophomore classes are expected to take one year of shop work, regardless of the course selected. The shop work is intended to be primarily educational, but the repair work incident to the operation of the establishment and the construction each year of some piece of machinery or apparatus, gives a taste of practical applications.

While the shop work has been carried on since the founding of the institution in 1872, the course in mechanical and electrical engineering, leading to the degree Bachelor of Science, was not organized until 1891. Since that time, the number of men graduated in that course, including the class of 1898, is sixty-six.

Of these—

38, or 57.6 per cent, are connected with practical engineering work.

7, or 10.6 per cent, are connected as professors or instructors with technical schools and colleges.

7 are engaged in commercial pursuits.

3 are farmers.

3 are lawyers.

2 are dentists.

1 is dead.

5 not reported.

It is thus seen that almost 70 per cent of these men have engaged in pursuits directly in line with their college training. We also have quite a number of special students,—men who, for various reasons, do not feel willing to spend the time necessary to complete the degree course and at the same time desire some training. From a list of twenty-five of these, almost every one is found to be engaged in some sort of technical work.

The earlier graduates had some trouble in overcoming the inertia of the old prejudice of practice against theory, and on account of this prejudice, several of them went north and secured positions in New York, Philadelphia, Washington, Pittsburg, and other centres of engineering activity. One of the boys who staid at home and fought it out, writing of some of his experiences, says, "When a young college man strikes a town like this it would be a great help to him to denounce colleges and professors as humbugs, or better still, to swear that he had never been in a town where there was a college. He should say 'I seen the machine sparking' and 'I taken some commutator compound and stopped it.' He should never make the mistake of expressing an opinion. When anything goes wrong, run to the boss and ask him what is the matter, and never dare question his decision. The superintendent of a certain lighting plant in which I worked could not tell whether the generators were series, shunt, or compound wound without referring to the catalogue, but he can put on a look of wisdom that would shame old Solomon and tell exactly what is the matter with the machine." These are the expressions of a bright, level-headed young fellow, who by sheer grit and ability has forced his way into a good position in one of the most prominent cities of the South. This case is not believed to be an unusual or exceptional one, and it serves to show the lack as well as the need of engineering education at that time. It is only fair to say that conditions are becoming greatly improved.

The home demand is growing and is now about equal to the supply. Out of seventeen senior and graduate students turned out last June, not more than two were without employment six weeks after graduation, the salaries ranging from $40 to $75 per month. The boys as a rule do well and win promotion, and many of them have grown into positions of importance and responsibility and command salaries to correspond. This success is, of course, gratifying to the instructors, and would seem to indicate that the course of study accomplishes, in some measure at least, the purposes for which it was arranged. It is not in any sense an ideal course. Even ideals depend largely on environment. The ideal engineering education so ably outlined by Professor Burr before this Society at its first meeting will doubtless serve as an ideal for the most advanced engineering colleges for years to come. In course of time, however, as the real approaches the ideal, another ideal will be set up. As for this present time, for many of us this ideal is so remote and inaccessible as to offer only cold discouragement in our efforts to attain it. We, then, must set up a lesser ideal, one to which we can more nearly approach, and one that offers inspiration rather than discouragement. We can not demand extensive preliminary education, neither can we afford to turn out men utterly lacking in general training. It follows, therefore, that there must be a compromise. We must make the man, first a good citizen, and then as much of an engineer as we can.

The prospect for the future is encouraging. The natural resources of some of the Southern States are unexcelled on the continent, and nothing can prevent their rapid development but an ignorant and mistaken policy on the part of the lawmakers and the people themselves. This proposed development contemplates vast engineering enterprises which, when carried out, can not fail to react favorably on the cause of engineering education in the adjacent territory.

THE MOUNTING AND USE OF A SPHERICAL BLACKBOARD.

BY ARTHUR EDWIN HAYNES,
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I. *The Board.*

(a) A spherical blackboard for class room use, in the teaching of spherical geometry, trigonometry and astronomy, is a piece of apparatus of great value when it is of a sufficient size, properly mounted, and skillfully handled.

The diameter of such a board should not be less than 18 inches, in order that the figures drawn upon its surface may be of sufficient size to be easily seen across a recitation room of ordinary dimensions.

The so-called "Yale globe," about three inches in diameter, answers a good purpose, as a piece of apparatus for the use of the *individual* student.

(b) The proper mounting of such a blackboard is a matter of no little importance; it should be so arranged as to readily admit of drawing arcs of more than 180 degrees upon its surface.

This feature is especially desirable in illustrating some of the theorems of the geometry of the sphere and many of the problems and phenomena of astronomy.

(c) It is also desirable that it should be easy to adjust and that it should have an easily detachable meridian as well as horizon: the two latter features being important only in illustrating the problems and mathematical phenomena of astronomy.

II. *Its Use.*

(a) Such a board is invaluable in securing a clear understanding of the relations of symmetrical spherical triangles and the method of finding the area of such a triangle, and is absolutely necessary in gaining a correct understanding of the position and form of polar triangles,—a subject presented in most of the text books on geometry in a very incomplete and misleading manner.

For example, most of these books on this subject, represent one form only of a spherical triangle and its polar: viz., that in which the original triangle and its polar are *alike* in form, one being wholly *within* the other, while the other cases, where they differ widely in form and where the sides of the one may cross those of the other or take various other interesting positions, are very seldom, if ever, shown: and so the student is left with a false impression with reference to such figures.

(b) This kind of board is useful in spherical trigonometry, when reviewing the relations of the sides and angles of polar triangles: in illustrating the method of solving the quadrantal triangle and the so-named "polar," or astronomical triangle: and also in illustrating the subject of "species" and the position of the side opposite the given angle in cases where two solutions are possible.

(c) Such a board has much value also in illustrating the various problems of astronomy, such as: having given the declination and the latitude, to find the time of sunrise or sunset, to find when twilight begins or ends; and, the foregoing elements being given, to find the time of day by the sun's altitude, etc.; or such as: having the right ascension and declination of a heavenly body, to find its latitude and longitude.

These and many other problems of a similar kind, as well as many of the interesting phenomena of astronomy, may be helpfully illustrated by such a blackboard with proper attachments and use.

III. Special Mounting.

The board herein represented is eighteen inches in diameter and is one which I secured *unmounted* for the College of Engineering, of the University of Minnesota, at about one third the expense of such a board when mounted.

I then designed and had made by the instructor in the wood-working shop of the college, the simple, cheap, and effective mounting represented in the accompanying drawing and photograph; see plates 1 and 2.

The total cost of the board with this mounting was about one half the cost of such a board already mounted and much less convenient. This mounting consists of a circular plank base with a circular semi-cylindrical groove upon its upper surface: above this and fastened to it by a bolt through its center is another similar disc of plank with a like groove on its under side immediately over the groove below: in the cylindrical groove thus formed are placed common marbles, and thus the upper disc easily rotates around the bolt, as an axis, carried on the marbles as a ball-bearing.

On the upper disc are three posts, bearing on their tops a circular wood ring large enough to permit the board or globe to drop into it about one fourth of its diameter: the globe, instead of resting directly on the ring, rests upon the heads of three rubber-headed tacks and upon a rubber cane-foot, placed over the extension of the axis. A simple quadrant of wood, bearing a crayon, completes the apparatus. It is thus seen that the globe can be easily moved about independent of its mounting while resting upon the wood ring, and when figures are drawn upon it, without changing its position in this ring-holder, it can be easily turned around so as to face any part of the room.

To fully complete this apparatus for astronomical purposes, upon this ring there may be easily arranged a movable horizon and a movable meridian.

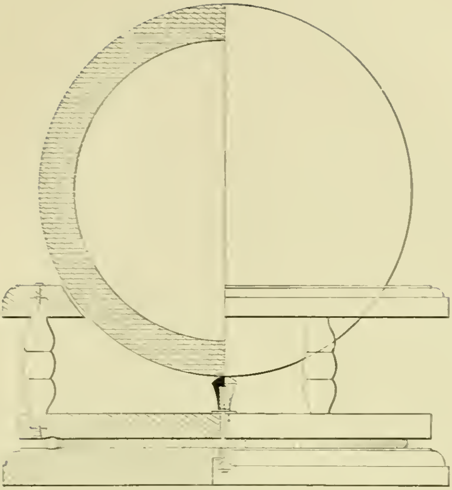

Plate 1.

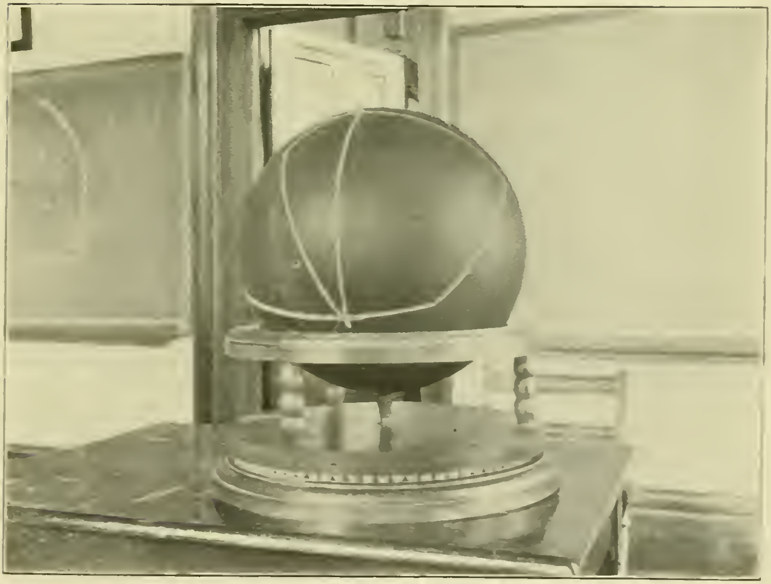

Plate 2.

DISCUSSION.

Professor Johnson thought it would be an improvement if some one would invent a dissected sphere for the purpose of teaching spherical trigonometry and solid geometry.

Dr. Mendenhall made a suggestion as to the best diameter for such a board as is described in the paper. In the speaker's experience he had found it almost invariably the case that with a spherical board one sooner or later wishes it to represent the earth. In that case, if the globe were sixteen inches in diameter instead of eighteen inches, then there would be a very simple and convenient unit of measure—five hundred miles to the inch. The speaker said that makers have persisted in making their globes with no simple ratio to the dimensions of the earth. The dimensions of a globe should be four inches in diameter, or eight inches, or sixteen or thirty-two inches, and so on—preferably eight inches, as then every inch might be taken to represent one thousand miles. The globe makers, curiously, have used three, six, nine, or eighteen inches, etc., which is entirely out of relation. The speaker further suggested that if Professor Haynes would prescribe sixteen inches instead of eighteen inches, it would be very much more useful.

UNDERGRADUATE THESIS WORK.

BY EDGAR MARBURG,

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Philadelphia, Pa.

The subject of this paper, in various phases, has received no little attention at past meetings of this Society. While former discussions have indicated at times marked differences of opinion, it is confidently believed that these differences are, on the whole, more apparent than real. Granting that the thesis deserves to be regarded as the most important feature of the undergraduate course, the subject seems to merit further consideration.

For undergraduate courses, the subject must be treated, in part, on an essentially different basis from that for advanced graduate courses. It has repeatedly been urged before this Society, that the thesis should be regarded as a formal test of the acquirements or capabilities of the student. Referring always to the undergraduate side of the question, the writer finds himself obliged to dissent from this view. He thinks that the thesis should be recognized simply as a somewhat advanced piece of work, intended primarily to further the student's knowledge in some particular direction. In most cases, it offers the only opportunity in the course for specialization. It is manifestly essential that the work should be conducted under regulations best calculated to promote habits of close, persevering, and, as far as possible, independent thought; in short, to develop mental self-reliance. But this is no less essential in every other branch of study. It is the highest aim, the goal, of all true teaching. It does not mark the thesis as a thing apart, save in the sense that the more advanced his preparation, the more mature his mind, the less the student stands in need of text and teacher. It is believed that the transition from the methods of instruction in the higher technical branches to those surrounding thesis work seldom is, and never should be, as violent a one as sometimes represented.

However the purpose of the thesis may be defined, the general policy controlling its preparation should be consistent with such avowed purpose. If the thesis is, indeed, to be mainly a test of the student's qualifications, it follows—as has, in fact, been argued—that in its preparation the student should be left wholly to his own devices and to the resources of the library, and that, no matter how good his will and effort, if the result falls below a certain indefinite standard, the luckless aspirant must forfeit his degree. That such a penalty is rarely or never enforced, except for flagrant delinquency, is hardly to be questioned. It would, indeed, be equivalent to confronting the student with the declaration that, while he has satisfied the prescribed standard in all subjects of his course, he has, in his thesis, unfortunately evinced his inability to make effective application of his knowledge to an independent piece of work, and that, consequently, the expected degree must be withheld. In the case of graduate students, the wisdom of such a policy is at least debatable; for undergraduates it is considered arbitrary and unjust, and is, as a matter of fact, probably seldom or never rigorously applied. The contention that the undergraduate thesis is a test of the candidate's fitness for his degree can be successfully maintained only if fairly in accord, not with ideal conceptions, but with actual practice.

There is, however, a more serious side to this question. If, on the ground that the thesis is primarily a test, the student is denied the helpful guidance of his instructor, it is held that his best interests will almost inevitably suffer. The subject may be of such a nature, or the student may be so talented, or may have derived such unusual advantages in practice, that the particular system prescribed for thesis work becomes itself of secondary importance. But it is the interest of the average, not the exceptional student, that should be held in view. It is contended that the average undergraduate can not reasonably be expected to prosecute an entirely independent—the term 'original' is purposely avoided—piece of work with full advantage to himself. He needs and should receive assistance of a kind that text and reference books do not, and can not, supply. This aid should come from the instructor. Not only is this duty regarded as his highest function, but it is believed that, in its conscientious discharge, none other is at once so interesting and so profitable, both to himself and to the student, as surely none is more exacting. It is unnecessary to emphasize the danger of allowing the student to lean unduly upon the teacher, nor the importance of exercising judicious discrimination in giving no more advice and direct assistance than seems essential. In connection with problems which the student may be reasonably expected to solve independently, even reference books should be interdicted; for certain other matters, he may be referred to particular publications, or better, in most cases, to the general indexes of engineering literature. But there are numerous questions that arise in almost every thesis to which the answer can come only from practical experience or sheer inspiration. If the individual concerned, whether student or instructor, lacks the advantage of practical experience, books frequently afford little or no compensation. And it is just such difficulties, each usually insignificant in itself, and easily dissolved by a timely hint from the experienced instructor, that prove so discouraging to the earnest student, so paralyzing to his best efforts, when left to flounder without the element of personal assistance. The writer would go so far as to express his serious conviction that the benefit derived from the average thesis is in no way commensurate with the value of that which, by an equal expenditure of time, might be accomplished through regular instruction, unless its preparation, from first to last, falls under the careful supervision of the teacher.

In the selection of the subject, the student should be given the widest latitude consistent with his own interests. Its general character will naturally be determined by his predilections, or by the nature of his prospective employment, or happily, by both combined. The special subject should always be selected in consultation with the instructor. A modest subject, thoroughly treated, is infinitely preferable to an over-ambitious project, handled in a loose and superficial fashion. The zealous student is not capable of fully recognizing the limitations imposed by inexperience and want of time.

Referring now more particularly to the needs of students in civil engineering, design work, or even an occasional résumé of some instructive subject, is considered preferable, generally speaking, to experimental work. Exceptions may be allowed in the case of men who have shown marked taste and aptitude for laboratory investigations and have given evidence of some mechanical ingenuity. The fact remains, however, that in a design or résumé, an excessive amount of routine work can, and always should be avoided, whereas with an experimental subject this is usually impracticable. The treatment of the latter easily degenerates into something little removed from the purely mechanical. There is the ever-present danger, not easily escaped, that the educational value of the thesis will be partly or wholly sacrificed in the search for definite, empiric laws. There is a strong tendency to blind ourselves to the fact that the training incidental to the planning of special apparatus for accomplishing certain desired ends, is vastly more beneficial to the student than the actual discovery of new physical relations, arrived at by oft-repeated operations. The mischievous tendency in undergraduate experimental work, to reject, upon inadequate or purely arbitrary grounds, results seemingly anomalous, and, again, of generalizing from insufficient data, is too well known to merit special comment. This reference is pertinent chiefly in that it emphasizes the importance of careful oversight.

Comparing the two broad classes of subjects—design and experiment—each in its most favorable form, it is believed that the value of the former, educationally, is at least as great; as a means of special, professional training, usually much greater than the latter. It is to be understood, as has been premised, that this conclusion is expressed with particular reference to the conceived needs of students in civil engineering. The professional duties of the mechanical and of the electrical engineer are more largely of an experimental nature, to which the technical courses preparatory to these branches should be more especially adapted. Efficiency tests of steam, gas, hydraulic, and electric apparatus offer an inviting and instructive field for the choice of subjects directly in line with subsequent professional duties.

The arrangement of the curriculum should be determined largely by the requirements for effective thesis work. Assuming the more usual division of the academic year, that of two terms, studies on which such work is commonly based should be completed during the first term, and there should be fewer prescribed hours for the second. While it is seldom practicable to make a very active beginning with the thesis before the opening of the second term, yet the choice of subject and certain preliminaries may well receive attention during the first half-year, at such odd hours as the earnest student can usually make available. This refers to such matters as the general outlines of the proposed treatment: the looking up of references; the planning of special apparatus: correspondence with manufacturers and the collection of materials for testing; practice in mechanical operations, such as the mixing and moulding of cement or concrete, with special regard to uniformity, etc. On this point, however, the writer does not speak from experience. It is merely a suggestion of what he has determined to try in the future. Delays and unsatisfactory results in some cases, which might readily have been obviated by more timely attention to preliminaries, have impressed him with the expediency of the course proposed.

Throughout the second term, weekly periods should be appointed for thesis work. In the writer's practice, three hours per week were originally devoted to this purpose. This has since been doubled to good advantage. The students are of course expected to accomplish as much as possible outside of these periods. The practice, believed to be rather exceptional, of having no set hours for thesis work is strongly deprecated. It seems to have little to commend it, except perhaps its convenience to the instructor. The appointment of fixed hours for this purpose insures the prompt initiation of the work and its regular, systematic prosecution. The student finds himself obliged to present at brief intervals direct evidence of his progress. It enables the instructor to judge at once where advice or admonition is needed and to keep continually in close touch with the work.

For certain kinds of subjects, involving extended calculations, drawings, or laboratory operations, the plan of allowing two students to work jointly has much in its favor. Such parts of the work as are mainly mechanical may be divided, while all computations may be performed independently and checked for errors. The general effect of such partnership is stimulating, tending, as it does, to engender a wholesome spirit of emulation. It invests the work with added interest and causes the average student to apply himself more assiduously than he would be apt to do singly. Such, at least, has been the writer's observation. With large classes, the consequent reduction in the number of subjects enables the instructor to maintain a better supervision. It is, of course, important that students thus mated should be fairly well balanced, not only in respect to general caliber, but in their taste for work. A shirk should be required to work singly.

The thesis usually affords opportunities for extended practice with the slide-rule, of which full advantage should be taken. Drawings should generally be made on tracing cloth, first, because this is customary in practice, and secondly, to enable the student to retain blue-prints of his work, which serves as an added incentive in calling forth his best efforts.

Referring, finally, to the literary and mechanical form of the thesis, the writer's views are substantially in accord with those expressed in an admirable paper presented at the last meeting of this Society. A comparatively small proportion of the students in technical courses have acquired, on graduation, a really good command of the English language. In some instances, the shortcomings in this respect are truly amazing, while pronounced exceptions, opposite in character, are comparatively rare. And yet, where the student has satisfied the language requirements of his course, it seems unjust to penalize him at the last on the faulty literary construction of his thesis, unless indeed, in case of willful dereliction. The difficulty in question is not only a most serious one, but one which lies unfortunately almost wholly beyond the reach of the instructor in engineering. Some good may be accomplished, however, by requiring the preparation of what may be termed 'summer memoirs' during the vacation periods immediately preceding the Junior and Senior years. These memoirs may treat of any subject of technical interest to the engineer. They should be suitably illustrated by sketches, photographs, or drawings, and all data should be obtained by direct personal inquiry and observation. It should be especially impressed upon the student that the logical presentation of the subject, together with clearness, conciseness and directness of style, are the first desiderata. These memoirs should be carefully examined and criticised, and may then be returned to the permanent keeping of their authors. The writer has followed this plan for some years with fairly satisfactory results. At certain institutions it has been in use for a much longer time. From its merit, it seems entitled to more general adoption.

In conclusion, it may be observed that no scheme for conducting thesis work can be devised which will insure satisfactory returns in all cases. Nevertheless, for the achievement of the best results—best in the sense of their highest value to the student—much depends upon the details of the system and more upon the conscientious and well-directed effort of the instructor.

DISCUSSION.

Professor L. J. Johnson asked Professor Marburg to explain more fully what he meant by "a résumé for the civil engineers."

Professor Marburg replied that he had chosen this somewhat indefinite term because of its comprehensiveness. He would not attempt to define its meaning more closely than to say that it referred to a summary—a careful digest—of the information obtainable on some engineering subject from all possible sources. The theme chosen should preferably be one of the many important minor subjects barely touched upon or wholly omitted in the regular course of instruction.

Professor Jackson said, with reference to design as compared with laboratory work in electrical engineering, that, as a rule, he had found the laboratory thesis work of rather more value. Most of the theses combine the two kinds of work; but the speaker's belief was that, as a rule, the men that have to go into the laboratory and manipulate, investigate, and overcome material difficulties, generally get better training from their work, and generally present more valuable results, than do the men that have not worked under these conditions. The speaker said he had frequently had a good deal of trouble with the question of "shirks," and in properly dividing the work so that the "pull" would be equal. He believed that in mechanical and electrical engineering it is ordinarily desirable that two men be assigned to each experiment; and he fully concurred with Professor Marburg that great care is essential in the selection of the right men to work together. Another point concerning which the speaker wished to say a few words was the supervision of the work and arrangement of hours. In his practice, no specific laboratory hours were assigned, the laboratories being kept open from morning until night; the students understanding that they must put in a certain stated number of hours' work. If the students wished to work double that time, they could do so, but a minimum limit was fixed. The number of hours for each thesis was posted, and an instructor was appointed to oversee the work and to keep the students properly directed, yet leaving them essentially independent investigators. The speaker thought that much of the success of the thesis depends upon the technical work of the course, preceding the thesis; that is, the instruction in the laboratory, drawing-room, and class room. The teaching may be such as to make a man competent to go ahead with independent investigation, or it may readily leave him helpless. The character of the thesis work is a measure of the efficiency of an educational institution.

PROFESSOR F. H. ROBINSON said he had thought for a long time that there is perhaps no subject of the curriculum in which there has been such discrepancy between theory and practice as in the subject of theses, and that we therefore appear in an unfair light to the students, to ourselves, and to those who are looking on. Certainly there is inconsistency in our representations of what the student is expected to do in the preparation of theses. It is sometimes intimated to the public that undergraduate students are doing things that in reality it is impossible for them to do. It seemed to the speaker that the key-note of the matter had been struck in the paper just read by Professor Marburg, in indicating that the thesis is logically a part of the instruction. The speaker expressed great satisfaction with the general views that were advanced in the paper, and especially with those concerning the writing of memoirs, which seemed to him to be a logical introduction to the preparation of the thesis.

PROFESSOR GRAY thought that the meaning of the requirement of undergraduate theses is generally changing and that the custom is drifting into a nominal agreement as to what undergraduates should be expected to do in regard to theses. It seemed to him unwise to expect that in undergraduate work the thesis should be a test for the degree; that is well enough in the case of candidacy for doctors' degree, etc., but in undergraduate work he thought it should be avoided as much as possible. He thought that in proportion to the time spent, the student gets more information from his thesis work than from the regular instruction work; he works more enthusiastically on the thesis than he does in the regular exercises, and the general results accomplished are much more satisfactory. In regard to the assistance to be given, the speaker thought as much assistance should be given the student as is necessary, at the same time leaving him practically the director of the investigation, if it be such, or of the design if it be a design. That is, the student should be assisted as much as possible in getting the maximum benefit out of the subject. As to the assignment of time: in the speaker's experience several plans had been tried; at one time one week in each month was given, the student to work continuously. This was generally satisfactory, but in one important particular it was not; namely, in the breaking up of the regular course work, as it was found impossible to get the student back in the same fresh condition to go on with his regular work. The speaker said that for two or three years his institution had been gradually changing its plans in regard to thesis work, it being generally thought wiser to entirely complete the regular course work about six weeks or two months before graduation and commencement, and to devote the remainder of the time continuously to thesis work. It was found that a student could accomplish vastly more in working continuously for five or six weeks, than he could by breaking up the work into a number of periods. The speaker thought that the questions as to the time at which the thesis should be decided upon and the manner in which it ought to be decided upon are also important. His experience had been to have the students themselves decide upon the subjects, with such advice as they may choose to ask from the instructors or others interested. The subject being decided upon, and approved, some member of the Faculty is assigned for the supervision of the work; he is expected to advise the student as to what works of reference will be suitable and to give such personal assistance as may seem necessary. The time of assigning the thesis is usually put several months before the period at which the thesis work is to be done, mainly for the purposes of obtaining references and making proper preparation for continuous work; also what is a very important factor in the case of investigation work or special tests, especially in mechanical engineering, to allow such time as is necessary to prepare special apparatus. It very commonly happens that after five or six weeks' work on a thesis, the student is only just ready to show the apparatus. Some little time should be allowed for such preparation.

THE CONSTRUCTION OF MODELS BY STUDENTS AS AN AID IN TEACHING DESCRIPTIVE GEOMETRY.

BY HENRY S. JACOBY.

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There is probably no course of study included in any curriculum for engineering students which appeals so much to the imagination as a thorough course in descriptive geometry. This statement does not apply merely to an extended course which includes the representation of surfaces of the second and higher orders, and the applications to tangency, intersections, development, shades, shadows, and perspective, but also to a short one which covers only the systematic development of the fundamental relations of the point, line, and plane, when represented by their projections, and which is commonly known as the elements of descriptive geometry. The principles governing these relations were first systematized by Gaspard Monge in 1794.

One of the reasons why a considerable number of the students taking this subject find it difficult is that their imagination has received but little, if any, vigorous exercise by their previous studies in the preparatory school or college. The intellectual discipline involved in the study of geometry comes, doubtless, the nearest to that required in descriptive geometry. Plane geometry makes but little demand upon the imagination, since the object represented may be regarded as coinciding with the diagram. In solid geometry the objects are usually represented in the text books by cabinet projections which give but approximate conceptions of the real forms, while sometimes they are misleading unless models are available to correct the student's first impressions. It is only quite recently that methods of illustration have been adopted which afford any adequate means of educating the student's imagination to a proper comprehension of the forms in solid geometry. This is done by the use of models consisting of the solid edges united as a framework, or with sides made transparent in many cases, so that all the edges of the figure can be seen from one point of view. An effort is made to extend the use of such fine collections of geometrical models to others than those having direct access to them, by printing photo-engravings side by side with skeleton diagrams. The lines of the latter are drawn parallel to the corresponding lines of the former and thus make the diagram a perspective drawing.

It is a moderately long step. however, from this representation, even at its best, to that used in elementary descriptive geometry, where two directions of the lines of sight are constantly employed. The need of models in the study of descriptive geometry is indicated by the fact that those colleges in which this subject holds its rightful place in the curriculum, and receives the treatment which its importance in engineering education demands, have collections of models which are more or less entensive. The Schroeder models in wood, the Muret collection in plaster, and the Olivier models in brass and thread on a wooden base, are probably the most widely distributed, and in many cases have served as copies for the construction of other models. In the College of Civil Engineering of Cornell University is a series of forty-seven adjustable models, made after the Olivier models, which have been reproduced in part by a number of other colleges in this country.

Most of these models, however, do not relate to the elements of descriptive geometry, but to the more advanced problems, which are strictly the applications of the principles developed in the elementary part of the course. While the value of these models is unquestioned, the need of models for the elementary problems is greater because it is at the beginning of the course that the relative success or failure of the student in dealing with this subject is determined.

So far as the writer knows there is but one set of models on sale which covers these problems. It consists of thirty little models made of cardboard, wire, and thread. Each of the planes of projection consists of a cardboard three inches long and about two and a quarter inches wide. The projections of points and lines and the traces of planes are drawn on the surface of the cardboard, and the two planes of projection are held at right angles to each other by means of bent wires. The lines in space usually consist of thread, although wire is sometimes used, while points in space are located by the vertex of the angle of a bent wire which forms its two projecting lines. These models, known as the Jullien models, are very ingeniously constructed and are so arranged as to be readily taken apart if for any reason this is desired.

The principal advantage of such models is that the student can hold them with the two planes actually horizontal and vertical, and see the true relation of the given point or line to its projections: first, by looking downward at it from above; and second, by looking at it from the front. In the first case he will see the vertical plane edgewise in the ground line and each point covering its horizontal projection, while in the second case he sees the horizontal plane in the ground line and each point covering its vertical projection. The consideration that it is practically impossible for the eye of the observer to be at infinity, makes it evident that this mathematical assumption to account for the parallelism of the projecting lines must be replaced by the requirement that the eye of the observer shall be moved about so as to be over each point in turn in order that the point shall cover its horizontal projection. As it is also practically impossible to view an object in two directions at right angles to each other at the same time, it is important that the student shall not consider both projections simultaneously, but shall imagine the surface of the drawing as occupying successively the true directions of the planes of projection whether it actually does so or not.

This relation of the drawing to the object in space is in harmony with the almost universal conditions in practice where the object remains stationary and the observer takes as many views from different directions as are necessary to give him a clear conception of the form and relation of all its parts. Nothing will help the student so much in keeping in mind the true relation of its projections to the object in space as a simple model. In the absence of models to correct the impression, perhaps no idea has been responsible for so much confusion as the customary statement in the text books that the vertical plane, together with the projections upon it, are to be revolved about the ground line into coincidence with the horizontal plane. This idea makes a demand upon the imagination of the student for which there is no necessity.

But it is not sufficient that the models are in the class room: the student needs their help in lesson preparation. The recognition of this need is indicated by the fact that in one of the most recent text-books thirty-one cabinet projections are employed in addition to the orthographic projections in the elementary problems alone. A series of stereoscopic diagrams is sold as a part of an older book in order to secure the same result. The chief defect of both of these substitutes for models is that they give a view of the object in a different direction from that in which either projection represents the object as seen, and hence give but little aid relatively in understanding the relation between the object in space and its projections. The writer's experience has been that it is difficult to induce the students to use the stereoscopic views, the reason assigned by them being that they saw so little use for them.

A picture or a cabinet projection may, however, serve a useful purpose in simplifying, by reference to it, the analysis of a problem or the verbal description of some operation which forms a part of the solution; as, for instance, in finding the angle between two planes. The model in this case shows clearly that the line which measures the altitude of the triangle whose upper angle is the required result is perpendicular to the line of intersection of the given planes, as may be seen when the observer looks directly toward the projecting plane of this line. The sides of the triangle consist of the lines cut respectively from the given planes and a plane of projection by an auxiliary plane perpendicular to both of the given planes.*

Such simple models of cardboard, wire and thread may be prepared by the student as a part of his lesson preparation with great benefit. The labor required is so slight that to any student whose imaginative power is not unusually strong the energy expended in this direction will not only secure clearer conceptions but will do so with an economy of time and effort over that required by any other means. While a considerable number in each class can succeed without any such help it is the opinion of the writer that even the best students will profit by the models at the very beginning of the course.

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*The model for this problem, as well as those described later, were exhibited in connection with the reading of the paper.—EDITORS.

It is not desirable that a model be examined, and much less, constructed, for all the problems; for most of them consist merely in combining two or more elementary operations, or in the application of principles deduced by logical reasoning, just as in any other branch of mathematics. Progress in the development of the imagination can thus be tested at intervals; and while it is true that many problems can be solved without making any effort to imagine the relative positions and directions of the component lines and planes in space, yet one of the most important results of the study of descriptive geometry is the power to conceive forms and relations in space of increasing complexity, by means of the study of their projections alone. On this account descriptive geometry is highly useful in engineering education, especially to the engineer who would design new constructions or rightly interpret the graphical representations of the designs of others.

There is perhaps no problem in the elements of this subject that shows the advantage of a model so well as that of constructing the projections of a line when its angles with both planes of projection are given. Assuming the line to be limited by its traces a line of the given length is drawn on a sheet of paper, and is made the common hypotenuse of two right triangles which respectively contain the given angles at the opposite ends of the hypotenuse. By creasing the paper along this line and trimming it along the outer lines of both triangles, the sheet may be effectively used to show the required double rotation of the triangles when held against a vertical and a horizontal plane as the planes of projection.

If the elementary part of the subject is mastered there will be but little occasion later for any models to be constructed by the student. In the intersection of surfaces, for instance, the knowledge of how to make the models comes after the period when their help is most needed. Paper models of the single curved surfaces may be readily constructed after their development is made, but this must follow the finding of the line of intersection for which the model is needed, if required at all. Models with threads for the elements of the surfaces require more time than the student can afford to give to their construction. The models in the class room will fully answer the student's purpose in this part of the course as there are but few points in any lesson which are not usually clear to the majority of the class.

The most useful class room models are those relating to the warped surfaces, whose forms are mostly new to the students. One nappe of the developable helicoid may be quickly constructed with paper since its developed form is bounded by a circle and its involute. By creasing the paper in the direction of a number of equidistant elements it can be made to stand on the horizontal plane without extra support.

To sum up: Models made by the student are of decided value in the early part of the course, and their use is recommended. They economize time in the study necessary to gain clear conceptions of the figures in space, both in their relation to their projections and to each other. They serve a more useful purpose than more elaborate models available only in the class room. In the application of the elements of descriptive geometry to the tangency and intersection of surfaces, and in the representation of warped surfaces, the class room models fully serve the needs of the student with perhaps a few exceptions.

It should perhaps be added, that in preparing this paper it has been assumed throughout that the aim of the course in descriptive geometry is not merely to enable the student to reproduce the solution of those special cases of problems which are given in full in the text book, but to develop his ability to apply the fundamental principles in the solution of original problems. The simple reproduction of a given construction may lead rather to an exercise of the memory than to that of the imagination; but if the assumed aim of the course is kept steadily in view the instruction in this subject will rightly perform its chief function.

An original problem does not always imply a test of the student's power of geometrical invention to make an entirely new application of principles or a new combination of the methods of preceding problems; but, more frequently, the solution of a problem of the same kind as the one treated in the text but in which the position and relation of the component points, lines and planes, or other geometrical figures, are entirely different. The solution in this case requires that the student shall not depend in any way upon the appearance of the diagram, but on his ability to make the construction in its most general form for each step in the method employed.

DISCUSSION.

Professor Bull said that it was his impression that models might be used altogether too much; that is, that by their use the very objects sought in teaching descriptive geometry would be entirely done away with. It is desirable to cultivate the imagination, and if models are used too freely this most valuable quality of the subject is lost.

Professor Kingsbury said that he fully agreed with the author of the paper concerning the extent to which models are useful, and that their utility is greatest in the cases of the fundamental problems in the beginning of the course. For the more advanced problems, it is often necessary to fully understand the problem before the model can be constructed. The speaker said that he usually showed his students how to make models of the single curved surfaces from sheets of paper by drawing the paper across the edge of a ruler, giving the ruler and the paper the proper relative motion to curl the paper into the form of the cylinder, the cone, or the developable helicoid, as desired. The edge of the ruler corresponds to the right-line generatrix, and the paper is curved continuously, not bent at intervals as in the models shown by the author. The speaker stated that it is easy to make both nappes of the developable helicoid, using two sheets of paper, properly cut and curled, and fastening them together along the directrix by means of gummed strips of paper or cloth; the models thus made are adjustable to any obliquity. He exhibited a model of this kind, which showed several turns of both nappes.

The speaker then referred to an error concerning the developable helicoid, the source of which he did not know, but which has been maintained for nearly forty years in at least one excellent and widely-used text book on descriptive geometry. The error lies in a statement that "any plane containing a rectilinear element is tangent to the surface at the point where the element touches the directrix." The error evidently arose from a confusion of this surface with the warped surfaces. The statement is readily disproved by analysis or by construction, by showing that the plane in general contains but one tangent to the surface, namely, the rectilinear element, and hence is not a tangent plane. This error, unimportant in itself, has almost invariably had the effect of confusing the student or of giving him an erroneous idea of the form of the surface near the directrix. The speaker said that he had been led to a recognition of the error, not by the construction of a model, but by making some drawings involving the application of the developable helicoid as the tooth-surface for skew-gears.

NOTES ON SOME METHODS IN USE IN AN ENGINEERING LABORATORY.

BY FRANCIS C. CALDWELL,
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The object of these notes is to call your attention to several matters that have proved of considerable service in our laboratory, in the hope that they may offer some useful suggestions to other members of the Society.

The first of these is a system of questions and answers upon the experiments to be performed, which, although similar to methods in vogue elsewhere, is, so far as I know, new in just this form, into which it has grown through several years of use. A sample set of these questions is given below. I have attempted to make them progressive, as far as possible, the earlier sets being very complete as to all details of the experiment, as in the example shown, while the latest sheets have little besides general instructions to describe the theory and practice of the operation.

II. SATURATION AND HYSTERESIS.

(a) What is a saturation curve?

(b) What is the difference between a saturation curve and an hysteresis curve?

(c) Sketch saturation curves of a dynamo, and of the iron part of its magnetic circuit, and explain the difference.

(d) What does the inclination of the curve to the X axis indicate? Make sketch.

(e) What the curvature? Sketch.

(f) How as to scale must curves of different machines be plotted to be comparable?

(g) What does the hysteresis curve show? Sketch.

(h) Suppose while increasing current you go too far, and then reduce it to the required value, what effect is produced on the curve?

(i) How reach the required value without this effect?

(j) How must the speed be kept?

(k) If the speed is not kept as above, how can the readings be corrected for it?

(l) Can the machine be self-exciting during the test? Why?

(Note—Regulate motor speed with resistance in its field.)

(m) Discuss process of obtaining hysteresis curve. Take complete hysteresis curve, and discuss it as indicating the characteristic qualities of the machine.

1897 Laboratory Notes, p. 16.

The student before performing the experiment is sent with this sheet to the Library, where are books in which he can find for himself the necessary information for the answers to the questions. He is thus obliged to become familiar with a number of reference books and their use. He writes his answers in a notebook, and these are looked over and criticised by the laboratory assistant before the experiment is proceeded with. My method is further seldom to answer a question directly, but either to refer to where the answer can be found, or by questions to draw out from the student himself the information wanted. I feel that too often a student is taught too much and educated too little; and this is an attempt to avoid this condition.

The second point to which I would draw your attention is the notebook.* The theory that we follow in regard to this is that a student should be taught to use a notebook in the laboratory as far as possible in the same way that he will use it after he leaves the University, and for this reason that he must not regard it as a copybook, to be valued chiefly for the niceness of its appearance. I accordingly require that all original notes and readings on tests shall be made at the time, in a permanent notebook, as neatly as the circumstances will permit, and that they shall be worked up in the same book. A standard notebook was desirable for this purpose, which should be durable, convenient, not too easily soiled, and should cost enough so that the student would value it from the start. The one here exhibited was accordingly designed, and in this form its use has been extended from our laboratory into most of the others in the University in which notebooks are required. They are kept at the University supply store, and cost the students twenty-five cents. Their principle peculiarities are the leather covers, convenient size for the pocket, and the ruling, which, adding to the ordinary cross-ruling, red lines five spaces apart and purple head lines, makes them convenient for columns of figures and also for simple curves, sketches, etc.

A third point upon which I am laying particular stress, is the frequent calibration of the instruments used, seeking to impress upon the student that an instrument does not necessarily read volts because it is so marked, nor, even if a good one, as such instruments go, does it necessarily read the same two weeks in succession. Toward this end we are fitting up a room especially for calibration and supplying it with all possible conveniences for the comparison of the instruments in use, with a Weston laboratory standard for voltage, and with this and a shunt resistance for current, it being my intention to require a calibration of all instruments during every test made.

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*A sample notebook was exhibited by the author.--EDITORS.

In connection with the above, I may describe a simple and convenient continuous resistance in use in this room. It is made from an ordinary twelve-inch by four-inch wooden pulley, mounted on a small shaft with a crank, and supported on a brass bed plate by two standards. This pulley is cut with an eighth-inch thread and wound with a fine resistance wire, the end connections being made by brushes bearing on strips on the edge of the pulley. The interesting feature of it, however, is the sliding contact, which, as the instrument is stationary, I have made by attaching a fine wire some four feet from the pulley, passing it over the same, and hanging a weight on the loose end. This weighted wire running in the thread makes the contact, and as the wheel is revolved is carried from side to side; it should be made of a softer wire than the resistance, so as to take the wear. The arrangement works perfectly, and is the height of simplicity.

ON THE ORGANIZATION OF ENGINEERING COURSES, AND ON ENTRANCE REQUIREMENTS FOR PROFESSIONAL SCHOOLS.

BY ROBERT H. THURSTON.

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It is proposed in this paper to consider, concisely and from a professional standpoint, the necessity of organization of professional schools, of engineering, particularly; not simply, however, in the interests of the individual, or even of the engineering profession, but, also and mainly, as a matter of statecraft and of protection of the best interests of the country and the highest phases of national life and progress. It is further proposed to consider, still more briefly, the proper method of organizing such professional institutions and especially their curricula, and the logical and best methods of discovering their essential, and their desirable, though non-essential, entrance-requirements, and, finally, of securing a proper and the best method of relating their courses of instruction to those of the academic schools, preparatory and other.

The following line of argument is one which, in effect, if not as specifically and as directly applied, has been held and with little or no attempt at contradiction, or even challenge, by every great philosopher and by every great statesman whose attention has been given to the subject of the education of a people for the life and work of a people, from the days of Plato— who implied if he does not explicitly state it in his *Republic* and in his *Laws*,—and the time of Aristotle— who inspired Alexander the Great, even in the midst of his grandest schemes of conquest with the idea—up to the time of Luther, of Comenius, of Des Cartes and of Milton—who would make every youth competent to discharge "justly, skilfully and magnanimously all the offices, both public and private, of peace and war"—and to the days of those French and those German statesmen who organized, for the first time in the history of the world, those forms and systems of union of lower and higher academic and technical education which are to-day making the Germans, particularly, the admiration and the apprehension of the remainder of the civilized world. This line of argument is that which gave Senator Morrill and his colleagues in the construction of the "Land Grant Bill" stimulus, courage and persistence, and it is this which made Ezra Cornell zealous to impart to his statecraft, when he sat as a senator in the state capitol at Albany, practicality and fruitfulness, and which induced him to turn his great fortune and his greater soul to the working out of its deductions. It is this line of argument which inspired Hiram Sibley with an ambition to provide opportunities for the poor but ambitious and deserving youth of later generations that might give them, not personal success, simply, but power of effectively promoting the best interests of their country and of their countrymen.

The education of a *man* should fit him to perform all the "offices, both public and private of peace and war." It should fit him, as Paley puts it, "for the sequel of his life." As Plato and as Herodotus would agree, it should prepare him to do his best part in the work of the world by a training which should include, not only the riding of a horse and the speaking of the truth, but the intelligent prosecution of his chosen vocation, and should give him the power of profiting by such leisure and such opportunity as might fairly be hoped for as its sequence. It should, as Milton insisted, include, for the classes able to give time and money to its acquisition, the languages and pure sciences, applied sciences and the arts, "fortification, enginery, architecture and navigation." It should include the useful and the ornamental accomplishments of the citizen and the gentleman, the union of a liberal education with that which, in our day, has come to be denominated technical and professional. William Petty's scheme of a "great technical college where all apprentices might learn the theory of their trades before being bound to their masters." and the grander plans of the Marquis of Worcester and of Bacon, the later reproduction of the idea of Aristotle and his disciples, as crystallized, two thousand years ago, in the great university—the real university—at Alexandria, were simply illustrations of the deductions of Plato and of Aristotle, and of Des Cartes and of Vaucanson. They were concrete conclusions of the argument.

The education of a *citizen* should fit him for his life's work, and for entering upon the path that his ambition may have laid out for him, beyond and above it. Milton's definition, for the average citizen, even of our own wonderfully favored country, would cover an elementary general and academic education, followed by a training in the principles underlying the art which he is to practice, with the end in view of making him in the highest degree helpful to himself, to his fellows, and to his country. Statesmen and philosophers, for now two thousand years, certainly, have recognized this, and one of the surest evidences and measures of progress toward civilization, in the nations of recent times, has been the gradual recognition of this principle by legislative and executive officers, and by public bodies actually carrying on the business of the nation. The great movement in this country which had its most marked illustration in the establishment of the "state colleges," and in land-grant endowments by the general government, in 1862, have been the evidences of recognition of the principle by our own usually over-practical legislators.

The education of the citizen, also, should prepare him, as a matter of prime importance, for the intelligent and conscientious performance of his duties as a responsible holder of the franchise. It is not at all to our credit, as individuals or as a nation, that it is possible, in this "free and enlightened age and country," for so many of our youth to attain the age of maturity and legal responsibility with so little realization of the nature or the seriousness of those responsibilities, and with such absolute ignorance of the proper methods of discharging those duties, whether of peace or of war.

The Education of a People is the First Duty of a Nation. Upon its perfection, and exact adaptation to the needs of the people and of the nation depends, ultimately, the progress or the relative decline of a country. The duty of statesmen, the highest interest of a people prescribe, next to the protection of the citizen against crime and illegal disturbance, next to the maintenance of the law and the preservation of peace, the training of the people in the ways in which wise and honest men should walk. This means the provision, by representative statesmen and legislatures, of every known and available means of promoting the advance of the people of the nation in individual and aggregate strength, in moral, intellectual and physical health. and in power of safe and efficient defense against all attacks from the outside or from treason within. This means the establishment of a system of universal and public education of all children and youth in not only the branches which are regarded as the essentials of a gymnastic education, but those which are the foundation of those arts and sciences and vocations and professions which make the material progress of a nation a possibility, and of which the perfecting makes the measure of not only material but also of intellectual and of even moral progress.

That phase of this "complete and perfect education" as Milton called it, which is to be here and now particularly considered is that division in which are to be taught the scientific bases of the arts of life and of the foundations of the nation's material prosperity and standing among civilized peoples.

Perhaps the most remarkable, though comparatively little known among educators, of all the books ever written, not even excepting Milton's "Tractate on Education," is that of the famous statesman, educator, naval architect and engineer, ship-builder and philanthropist, John Scott Russell. His eloquent and strikingly earnest comment upon the progress of the then leading nation of the world in the organization of a national system of training of a people for the "sequel of their lives" will bear frequent repetition, and should be read by every educator and by every statesman in our broad land. I propose to abstract liberally from this great work in introducing this subject for present discussion. Russell, in his "Technical Education,"* says:

"The whole education of a nation may be divided into two great classes: (1) That which educates and matures the man, and which we call general education; and (2) that which specially qualifies the citizen for fulfilling that narrow round of duties which the subdivision of labor in civilized communities imposes on the individual as his special contribution to the commonwealth, and which we may call special or technical."

He shows the absolute necessity, as a matter both of ordinary justice and of political prudence, wisdom and statecraft, as an essential prerequisite of a well-planned and fruitful and successful life for the individual, and of political and economic and industrial independence for the nation, of the provision, liberally and generously, by the state, of both these sorts of education and training, and also of the provision of legal methods that shall effectively insure that the people take full advantage of them in all appropriate ways and in consonance with the best interests of every class in the community. Thus the intellectual side of the citizen shall be stimulated, the moral side given opportunity for growth and the industrial position of the country made such as will insure safety against foreign competition affecting the wealth-accumulating and usefully-productive powers of the people. Russell finds in Germany the highest development of such systematic and wisely-planned public education, including such as will meet the wants of the most fortunate by the provision of schools and colleges and universities for liberal education, and such as will anticipate the needs of the average citizen seeking such a training for his children as shall give them the highest possible combination of intelligence and producing power, through manual training and trade schools and professional schools of engineering. He remarks:

**Systematic Technical Education*; John Scott Russell; London, 1869. Note especially the splendid introductory appeal to his Queen.

"It is much to the credit of the German character that a nation to whom we have always accorded high praise for theoretical learning and abstract philosophy, should have outstripped us by a whole generation or more in foresight and farsight; and should have taken measures to promote the application of all the discoveries of abstract science to the speediest, wisest, and most economical solution of the practical problems of daily life and business.''

Referring to the report of a committee of eighty-six workmen and foremen from British shops, visiting Germany for the purpose of judging for themselves what was the real importance of the rumored threat of German industrial supremacy and its possible fatal influence upon British industrial interests, a supremacy due to the systematic and universal organization of the technical and professional side of German popular education, it is remarked:

''It is impossible to go through the evidence of the eighty-six representatives of the skilled workmen of England without sharing their profound conviction: 1st. Of the pressing peril of the nation in regard to manufacturing pre-eminence; 2d, of the culpability of the educated classes and of the executive government in having neglected the education of the people; 3d, that it is satisfactorily proved by these reports that the reluctance of the working classes to receive superior technical education, to bear taxation for that purpose, and to accept the active agency of government institutions and officials (which reluctance has been put forward as an excuse for this neglect), has no existence in fact, and that it is, therefore, the negligence, apathy, and reluctance of the governing classes and the government which have hitherto alone prevented the organization of systematic technical education.''

The following eloquent and impressive passage should be read and reread by every educator in the land, by every good citizen, and, above all and most attentively and thoughtfully, by every citizen in public life who has the slightest aspiration to become successful or to be honored as a statesman; for there is no higher, nobler, or more promising field of duty for the man who would follow the thought of Plato, the system of Aristotle, the ideal of Milton, or the admirable example of practical and productive and splendidly fruitful statecraft of the Germans, than this of giving to his country and his people such ''complete and perfect education'' as shall, as only can, provide for their highest and greatest needs and aspirations:

''Twenty years ago, professional duty took me to Germany for the first time. I can not forget my impression at the sight of whole nations growing up in the full enjoyment of systematic, organized, I might almost say perfect, education. I had already become acquainted with some theories and forms of education. I had read Plato's description of the perfect training for a nation. I was familiar with elementary school-teaching, and enjoyed the privileges of university education and the still higher education of the workshop. I was familiar with the systems of Bell and Lancaster, having had personal acquaintance with its authors, and had myself taken an active part in schools of art and mechanics' institutions; but I confess to have been profoundly astonished—I may say humiliated—at the sight of nations whose rulers had chosen to undertake the systematic education of their people, and of peoples who had chosen to bear the burdens and to make the sacrifices necessary to obtain it. I do not know to what men or class of men in Germany the forethought, organization, and patriotism are to be attributed which made them lay aside personal ambition, political animosity, religious sectarianism, and state parsimony in order to unite all the classes of people in a unanimous effort to raise every rank in society to a higher condition of personal excellence and usefulness, and, by diffusing equality of education, to extinguish the most grievous of class distinctions."

A personal examination of the German system of education led to the discovery that it included, in highest perfection, though by no means even yet in perfect form, the provision of not only what Huxley indicated as ideal perfection, a "ladder from the gutter to the university," but the full rounding out of the "complete and perfect education"—including the learning underlying all the sciences, all the literatures, all the arts, even, of the time, just as far and just as perfectly as the nation had been able to give them form. He found that not only was there provided, for all who could reach and intellectually profit by it, a system of liberal and classical education, complete and perfect, "from the gutter to the university," but also technical and trade systems of instruction and training, leading from the lowest levels of the primary schools to the noblest altitudes of the technical university. The technical university—or what, in our own country, is its representative in better form and more efficient operation, the university, *including* the academic and technical, the scientific and the linguistic departments, as well as the usefully applied sciences of the industrial arts in technical schools and colleges—was new to this clear-sighted and large minded philosopher, and he exclaimed, on discovering this true university system and the previously missing elements:

"A technical university abroad was to me a surprise, a profound lesson, a delight. It was a dream of my youth suddenly embodied in living substance: and, unlike other realized dreams, the reality excelled the fiction. It was one of my early dreams, that highly educated men should engage themselves in teaching skilled workmen the profound philosophical principles which underlie all material work: and, I hoped, so to make their work their pleasure: excellence their ultimate aim: truth of execution, and perfection of finish, their highest ambition."

In our own country, we are developing what is proving by experience, I think, to be the better method of providing for all classes all needed forms of education and training—the real university in which, for the first time since Ptolemy Soter and his, for its time, true university, a grander ideal than was held by any older philospher or educator or statesman,—simply because of the fact that modern life gives familiarity with a broader pantology,—a more perfect form of university. Our "state colleges" and universities are disproving the assertions of early timid or hostile educators, and are offering, often in one great institution, the whole range of pure and applied sciences, all the literatures and all the technical departments of study, and even a systematic development of highest practice.

As remarked by the writer in one of his regular reports to the Board of Trustees of Sibley College:

"There formerly existed, among the members of the profession a strong impression, one which, it must be confessed, has some justification in the experience of the past, throughout the world, that a technical school can not be made to succeed, fully and satisfactorily, as a part of an organization including academic schools; but that in the presence of these apparently conflicting interests the school of engineering must suffer, if not absolutely fail. This conviction was expressed very strongly by President Eliott, of Harvard, and still more so by the German educator, Professor Reuleaux, the head of the great technical university at Berlin, and who is by many regarded as the leader in the profession in Europe. In his address entitled '*Cultur und Technik*,' he says that 'notwithstanding their intended pursuit of a strictly scientific aim, the technical schools have not concluded their peace with the universities. Even with the best of good will, none of our efforts toward a real amalgamation of the two has ever been successful.' He quotes Professor Koechly, who says: 'And if not side by side, at least we can fight back to back,' in the great contest with ignorance and barbarism. He considers this unfortunate difference as arising from inherent differences in aim, and goes on to say that a blending of the two movements has been tried in the United States, our universities being both classic and technic, but that 'the experiences hitherto gathered have not shown, so far as observation permits a judgment, that the union can be permanently maintained, or that it has furthered the interests of education in the way that legislators had anticipated.' "*

It was felt that, in presence of this pronounced feeling, on the part of professional and educator alike, it would be desirable to set apart the proposed school, at least in its essentials, and give it an opportunity of growth which, up to that time, experience had seemed to indicate could only come when courses could be planned and work carried on under the direction of professional technical educators. The result has been satisfactory; and it has also indicated that the dangers feared from incorporation with other schools were perhaps not as serious as was then anticipated. But, at the time, all experience indicated that only independent schools were successful, or likely to be, on either side the Atlantic.

In Europe, however, this separation has been generally maintained, and yet Russell finds, in the new and still dissevered members of the great educational system, a wonderful completeness and symmetry. He says of the Zurich school:

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*Sibley College; Director's Reports; 1885.

"It is the great extent, completeness, and symmetry everywhere apparent in the organization of this great technical university which make it pre-eminently a model for us; not to copy or imitate merely, but to excel and go beyond. We must determine, as they did, not merely to copy some local institution in another country, which had to be fitted into the existing institutions of an entirely local character, but to supply, in a symmetrical and complete manner, every existing deficiency in the whole national system of higher education. The founders of the Swiss Polytechnicum did not therefore ask themselves the question: What is the smallest and least costly scale on which we can begin to make good a few technical deficiencies?—but they asked themselves this other question: What is there in the science, the philosophy, the learning, the art, and the practical skill of modern times which can be learned and taught, or which has been taught or learned in any other school of knowledge, but for which there is no adequate provision already made for teaching to our students in the university of the land?—and those things we will see to having thoroughly taught."

At that time, the British nation had become somewhat awakened to the dangers with which the greater foresight and wisdom of the continental nations were threatening it, and some of the leaders of thought, and the wiser statesmen, having souls lifted above the common level of petty politics, were studying the problem with a real intent of seeking safety by energetically, though tardily, adopting the same wise methods of regeneration of the people. Russell, noting this fact, says:

"I will take it for granted that we are in earnest in our wish that the best men of the nation shall be selected to teach our children their duties in life; that the highest honors we can bestow, social rank and independence shall be theirs; and I will now indicate shortly the system of teaching which appears to me most likely to meet the varied wants of our youth, and to qualify them to follow us in life. I have already said that the whole course of technical teaching must take a hue of usefulness, and that purpose and application must characterize it from the beginning. How this is to be accomplished will not seem easy to those who have never done it or seen it done; but to me it seems not only easy, but the most agreeable and efficient mode of teaching. For to tell a youth that to-day's task will one day be useful to him is to add value to his day's work; and to show him how a principle is to be applied, will both give it additional hold on his memory, and help him to see through its essence and nature; in short, the use will illustrate the theory."

Germany had, in earlier days, found herself far behind Great Britain in the race of progress, largely because of the marvelous good fortune of the latter nation in having in its midst the inventors of the modern forms of steam-engine, of the spinning frame and the power-loom—in possessing mechanical genius, in fact. The wise administrators of the German government and of her municipal affairs saw their disadvantage clearly. Scott Russell says:

"And they argued thus:—The one thing we can set against English wealth in raw material is greater skill in using what we have. The way to compete with them in mechanical power is to apply higher science in the treatment and application of it; and the way to compete with them in iron and skill is to buy of them the unwrought material, which they will sell us at nearly cost-price, in consequence of their free trade and close competition, and then to apply the skill of our own artisans, highly educated and trained, to construct out of these raw materials all the higher kinds of tools, instruments, and machinery in those forms and applications which enhance to the highest degree the value of the material."

In other words, wisdom and statecraft were set against natural talent and industrial advantage and a mighty leadership in manufactures. Wisdom and a splendid statecraft persevered, not for one year, not for a decade, or even a generation, but for decades and for generations; and to-day sees the reward in a magnificent success.

The great writer whose words are here so liberally quoted proposed the establishment in Great Britain of broad foundations for "technical universities," colleges of the constructive professions, of the trades and of applied sciences and arts. These he would place at such an altitude as respected constitution and personnel as should insure that the source of this useful knowledge should be well above the level to be supplied by its generous floods. He would have his countrymen do even better than their rivals and look forward to successful competition in the race through greater perfection of the same methods which had, at the moment, given those rivals such gain in relative position. He says:

"If our technical university is to be successful, its machinery of teaching must be of a higher and more powerful kind than any we are yet used to in England. For the teaching of our science we must have the most distinguished men our country affords; we must give them an income as large as that of a bishop or a judge; and as their success or their failure is to measure the success in life or the failure of our own children, we must treat them with the same consideration as we should show to a great relation who we expected to bequeath them a fortune. There is no training for life half so good as to give the youth an early association with men of genius and ability."

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"The technical colleges and technical schools which train students for the technical university can not exist sufficiently without the simultaneous existence over them of that university for which their highest and best pupils are to be prepared, and where these students are to find the highest reward and appreciation and consummation of their studies. Where they leave off, the university begins. Where the technical schools leave off, the technical colleges begin. Thus the whole national teaching must be one complete organized whole, or it will prove waste and failure."*

It was not sufficient, it was discovered on the continent, very promptly, that the technical side of education of the "industrial classes" should be provided with the highest and broadest curricula. The most common and most modest of the trades must be particularly cared for. Professional engineering schools, schools of architecture and of industrial art must be complemented by trade-schools; and the children, even, must be given opportunities, in kindergarten, and manual training schools, to cultivate their natural physical powers by exercise in ways that gave at once delight and profitable culture.

"For these great and wise purposes some of the most distinguished directors of the technical university, after many years' experience of the value of such education to skilled craftsmen, and the incompatibility of giving the highest and broadest education, equally with the narrowest and humblest, in the same institution, represented to the government the expediency of forming a new school, intended for building crafts and tradesmen of the rank immediately under the professional men and the skilled masters of the technical university. That was accordingly established and

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***Systematic Technical Education for the English People*, by J. Scott Russell, 1869.

succeeded so quickly and so completely that it became necessary to erect quite as large and as handsome a building, and to devote quite as large a staff to that purpose, as to the original polytechnic university; it is now one of the most remarkable and meritorious schools on the Continent. The men whom it was especially designed to help in their trades were stonemasons, bricklayers, and carpenters, to be trained for future master-builders; lower-class builders to be trained for master-builders, constructors of public works, subterranean works, and constructors of reservoirs; constructors of water-works, river-works, and mill-works, and land-surveyors of the first and second class."

"I may add" (continues our author) "that in every country where technical education has taken root and had time to bear fruit I also find unquestionable proofs of the rapidity with which increased intelligence and enlarged knowledge bring increase in employment and remuneration. From my personal experience I may say that within the last twenty-five years I have seen large branches of commercial trade leave one country and plant themselves in another because the workers of the one were educated and those of the other uneducated; and I have watched nations rising into importance and power in Europe by education, and by the order, organization, and efficiency which education bestows; and other nations lagging behind and losing their place by reason of their unwillingness to educate either the higher or the lower classes of their people."

He criticises the older educational methods and their institutions; not so much for what they have done and are doing as for what they lack of the universality and generosity and equality of opportunity for all which should characterize every "complete and perfect" system of education.

He frankly says: "What I blame in most of the institutions I have seen is the weakness of one sidedness. One university is famous for its experimental chemical research. What I want is, that our university should be famous equally for abstract reasoning and experimental research; equally for teaching the head, the hands and the senses; equally for persuading by reason and by experience. And in regard to the order of the teaching, I think that the best method is—first, to teach students what they are to expect; next to show them what actually happens, in fact, under their own observation, and by their own experiment; thirdly to teach them the reasons of that which they have already found to be the fact: and lastly, to teach them the methods of predicting that which has not yet come to pass. It is this union of education in fact, with education in thought, which gives to the human mind the empire of matter."

What is wanted in our day is that complete and perfect representative of one great and all-embracing system which shall, for its time, do what was done by the grandest of all ancient institutions, the greatest of all the ancient "wonders of the world," in its day:—offer to all comers opportunity to study and to pursue all the sciences, all the literatures and all the arts of the contemporary civilization. Ezra Cornell expressed the ideas of Plato and of Aristotle and of Milton and of John Scott Russell in a sentence:—"I would found an institution in which any person can find instruction in any study."

This Cornellian ambition, absurd as it may seem to the dull plodder in the ways of the mediaeval educator and of the monastic regime, is precisely that of the German Empire and of its constituent political elements of the earlier generations, certainly since the time of Luther.

Once it is recognized as a great principle of politics and economics that the primary duty of the state—given a system of government which steadily maintains the law and preserves the peace—is to see that the people are taught to make themselves competent to make the most of life and of the marvelous opportunities which modern civilization presents to all men, the obvious universality of the scheme of public education and training "for the sequel of the lives" of citizens is instantly recognized and its practicability in a reasonable sense as well; for the powers of the state are to be invoked to their utmost limits. Such power, in Germany, has been applied successfully to the solution of this great problem; in large degree, at least, by organization of the two principal classes of educational institutions, the academic universities and the technical schools and colleges and even, here and there, what may fairly be termed a "technical university." In our own country, the same object is gradually being attained through the state systems of general education, supplemented by the state universities, in which both the academic and the technical and professional divisions work, usually harmoniously and with mutual advantage, side by side, within the same organization, within what are coming to be the first real universities, in a true sense, that the world has seen since the days of Ptolemy Soter, and of the Alexandrian faculties.

As to method of procedure, we find the following:

"At first the various governments of Germany proceeded by setting a foot a number of inquiries into the causes of an evident inferiority, and found (1) that requisite technical knowledge was wanting among laborers, a knowledge which could be acquired only in suitable schools: (2) that every industry, if successful in the world's markets, relies upon the technical knowledge and ability accumulated in a community by years of skilled labor, not to say transmitted from father to son: hence that special excellence in any branch of industry is a result of both technical schooling and acquired skill. Instances were the cutlery industry at Solingen, the silk industry at Crefeld, the toy industry at Thuringia and Saxony, and the furniture industry at Berlin.

"The commissioners, examining into the causes of the German industrial decadence, agreed that the excellent results in the French textile industries and the great value of the products of French art industry were owing, not only to great innate talent of French laborers, but also to their thorough and very appropriate schooling in designing and manual labor. This special education for the purpose had been going on in France from the time of Colbert, the minister of finance during the reign of Louis XIV. Indisputable evidences of this were furnished by the various world's expositions, which opened the eyes of intelligent Germans to the inadequacy of institutions for industrial education prior to 1876. It may be said that German industry thereupon took an upward start most gratifying in its results; since it was consistently planned, and was aided by the establishment of a large number of institutions for technical and industrial pursuits.

"These institutions are of a threefold kind: (1) elementary industrial schools, which prepare the mass of laboring people; (2) secondary industrial schools, which prepare the foreman and designers, and (3) higher institutions, like polytechnic and art schools, which prepare engineers and industrial leaders.

"Of course there were already in existence some schools of each kind previous to 1876; but the State governments now began to foster industrial education by subsidizing schools established for that purpose. The communities usually furnished buildings and adequate equipment, and paid for light and fuel, and the

State would then defray a large part, and in many cases all, of the expenses for salaries of teachers."

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"The State authorities were not satisfied with providing for elementary work; they also encouraged the communities to establish secondary industrial schools, chiefly schools of design, in which drawing and mathematics claim three-fifths of the time devoted to study. These "*Gewerbe-schulen*," all of which are day and evening schools, are found only in the large industrial centers of the Empire. They have exerted an influence upon the laboring community far beyond anything expected of them. Each of these schools has a preparatory department with a one-year course. In this department the student is brought face to face with an almost bewildering variety of designs and occupations, at any or all of which he may try his hand. Soon he finds his favorite occupation, if he has not previously developed a special liking. Toward the end of the year he has, in most cases, a decided leaning in one direction, and the professors foster it by giving the pupil work to do that will help him on in his chosen specialty."

"Side by side with these schools of design there are actual trade-schools, also of a secondary character. These are not, like the '*Gewerbe-schulen*,' schools of industrial art—that is, nurseries of invention and design—but are intended to directly aid the trades by shortening the period of apprenticeship and developing skill in manual labor. Naturally the mental work of these schools consists in mathematics, drawing, and commercial science, besides giving the various bearings of each trade taught. These advanced trade-schools are found in industrial centers only. While higher agricultural, forestry, and mining schools are taken care of exclusively by the State, the trade-schools are established by the communities and generously subsidized by the State."

"All the schools mentioned—(a) elementary, industrial and agricultural schools (so called supplementary schools), (b) schools of design for the industrial arts, and (c) purely trade-schools—are specially designed to aid the community in which and by which they are established. The State, as such, does not establish them. They form no uniform system; no two of them have the same course of study, nor is the course of study of any of these schools intended to remain unchanged. It is changed as often as necessity and the demands of the locality require."

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"The German states are primarily concerned about schools that give elementary education; next, each state establishes and maintains secondary schools that lead up to the University; and, lastly, it provides for higher education in universities and polytechnica. These state institutions all aim at general culture, and form the state school system. Technical, trade, industrial, commercial, and agricultural schools of lower and advanced grade are special schools which are independent of uniform regulations. Their establishment is left to the initiative of private citizens or the communities. When they show that they meet the local needs of the community and are likely to indirectly benefit the state, the latter is petitioned for a subsidy, which is rarely denied. This is the reason why we find a silk weaving school in Crefeld and one in Saxony, and a braiders' school in Berlin, where much cane furniture is manufactured."*

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"It is no wonder that the public affairs of the state are increased by the task which affects the life of broadest layers of society if we consider that one of the characteristic signs of the time is the rapid extension of the area of state's duties. We now establish institutions with state aid for the solution of social problems where formerly individuals attempted it with limited means. In the field of education the state began with universities and reached further and further down till at present the master workmen are released from training their apprentices, or, in cases where they still keep apprentices, the master workmen are made organs of the state, i. e., state teachers."

"It is characteristic of the trade school in Berne" (for example) "that it combines a large number of trades, so as to give its students not only all the bearings of his own trade, but also knowledge of its relation with others. This school is intended to be not only an industrial education institution, but also a place where the students can earn money in working at their trades. According to the regulations in force, the school has the aim (1) to enable young men to learn a trade; (2) to enable young men who have learned a trade in some workshop to complete their technical education practically and theoretically, so as to prepare themselves for higher positions than that of laborers; (3) to check the immigration of skilled workmen from other countries and to elevate the Swiss laborers to a higher level of culture; (4) to elevate the trades in general. The means needed to carry on this extensive school are furnished by the community, partly also by the cantonal and the Federal Government, and lastly through the sale of the products of labor in the shops. Instruction is entirely gratuitous. An exhibition of the students' work is held annually, and the graduates of the institution are examined under the rules in force for apprentices (quoted in a foregoing paragraph)."*

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*In a governmental report on the Berlin trade and industrial, as well as supplementary, schools, published in Berlin in February, 1897, the entire number of students attending these schools is found to be 14,750, or about one per cent of the population. These students represent 160 different trades or occupations. The joiners (837), locksmiths (1,420), machinists (1,139), machine builders (919), typographers (563), and commercial students (2,549) are the most numerous.

It is somewhat singular that, in our own country, a country for which we are accustomed to claim so much and in which the industries have made such tremendous strides and which receives from the world such general commendation for intelligence, for enterprise and for care of the best interests of the whole people, so little attention should have been given to educational matters, even by professional educators, by public men and by the most able of our statesmen and philanthropists—so little, in fact, as to permit the facts here outlined to have apparently escaped the most observant among them; while the great mass, like the people themselves, plod along in the old ways, very generally, and are utterly ignorant of the progress of the world beyond the Atlantic. The few exceptions, like Senator Morrill and his coadjutors, on this side, like the famous and prescient British author from whom I have quoted, have, it is true, accomplished much in this last generation; but our educators, as a body, our lawmakers, our statesmen, as a rule, our philanthropists and our people, as a whole, have not made the most insignificant beginning of that "complete and perfect" system of education of a nation which should have occupied the attention of all from the primary period of the republic. Germany offers us the best example, to-day; but Germany has not even yet effected an ideal organization, in which the training of the people as a whole and the safe establishment of their industrial system, the foundation of their intellectual and of their moral life, is made the object of a systematic and logical construction reaching from lowest to highest and giving opportunity to all.

**Industrial Education in Central Europe*—Education Report, 1895-6.

Fortunately, we have, in our state and privately endowed technical instruction, alike, given large attention to the scientific substructure of the principal manufacturing industries; and the powerful and intelligent interest of our agriculturists with our legislative bodies has insured provision for not only agricultural schools with comparatively excellent endowments and equipments, but also for, if possible, still more essential "experiment stations," in every state.

Referring to the former class of technical curricula, Russell remarks:

"There are no occupations or trades concerning which there could be so little difference of opinion as to the practical importance of special technical education as the classes of mechanical engineer and of machinist. Philosophers have defined man as the tool-using animal; but if the man of this century were defined, the "engine-maker" and "machine-user" would be his leading characteristic; it is the triumph of human nature in our time, that it has achieved the understanding of the forces of nature so completely that, whatever material service we wish to perform, we can always discover some elementary force in nature willing to lend us its aid to conquer our difficulty, provided we study its nature sufficiently to direct it into the way in which it can best serve our end. The steam-hammer of Nasmyth, and the steel ingots of Krupp, are symbols of the powerful yet plastic forces man wields in his gigantic shape-compelling processes of manufacture. We may sum up the duties of a man of this craft by saying, that there is scarcely a process now performed by animal or man which our engineers or machinists of the next generation may not be called upon to perform better and quicker by machines of their own creation.

"Of the engineer and machinist it is therefore very easy to indicate the course of instruction; unluckily, much easier to indicate than to accomplish. He must master all the known powers of material nature: heat and cold; weight and impulse; matter in all conditions—liquid, solid, and gaseous; standing or running, condensed or rare, adamantine or plastic—all must be seen through and comprehended by the master of modern mechanics. The same laws which govern the machinery of the heavens, he has to apply to the machinery of the earth; and the same exquisite mechanism which the Creator has used in the structure of his animals the modern mechanician has to apply in the construction of his microcosms. The modern mechanician, who would be equal to his work, must be prepared to shape a tool and frame an engine for the execution of tasks which were never even dreamt of by the older mechanicians."

Russell, in his remarkable treatise, gives extensive and wonderfully well-considered curricula, or general outlines of courses of study, for this, as for a variety of other hardly less important branches of technical study and training, which we have here neither time nor a proper place to follow and discuss; only one feature we may perhaps venture to note. He would supplement every department of technical education and industrial training by the study of the products of its industry, as illustrated by the collection of the principal forms of such product in museums as complete and as carefully and as logically arranged and catalogued as are those of our older departments of natural history. For example, and as illustrating one of the most interesting as well as important of these schools of industrial education, he thus refers to the conception which he has formed of the character and arrangement of the museum of mechanics; which he would assemble in a great "Hall of Mechanics," as a central feature of the college devoted to this department:

"The hall of mechanics must contain those more complicated means of working matter which are in effect tools, but which, by means of a complicated mechanism, perform the multifarious operations which a human being has to devote all his skill to performing, and are yet, by their structure, able to do skilled work without skill. Modern mechanism presents an enormous field for the study of the student, and no collection could be more profitable than one which should unite in the same hall, under the daily notice of the student, all those thousand ingenious devices by which, out of a single moving force, an infinite variety of complicated and intricate movements are simultaneously performed. No branch of multifarious modern invention plays a greater part in civilized society than the dead mechanism which is continually performing the work of millions of human hands.

"The hall of engines should contain an even more wonderful and instructive collection than the hall of tools and machines. Engines do not merely perform the work of human hands; they create living power out of dead matter, and relieve men from the degrading task of being the mere drivers of dead mechanism. Engines may be said to create living things. An engine of one hundred horse's power is an engine able to do the work of four hundred living horses, and able to do it not for eight hours a day only, but for twenty-four, and all the year round. The future of the world, and of the human race, depends far more upon the steam engines and water engines, the fire engines and air engines, the magnetic engines and the electric engines, yet to be invented and made, than upon the labor of all the horses and oxen in the world."

Says Mr. S. N. D. North, the Secretary of the National Association of Wool Manufacturers, in an article in *The Forum*: "The record of German progress is most significant. Applying the test usually made, we find that German commerce has increased from 180,000,000 in 1850 to 815,000,000 in 1889, the percentage of increase being three hundred and fifty as compared with one hundred and fifty per cent of increase in British commerce. Admitting that these percentages are not a fair test, it must nevertheless be agreed that German progress has been much the faster of the two and very much faster when we consider the relative disadvantages under which Germany started in the race. In twenty years Germany had doubled her exports and lifted herself to a point of vantage equal to that at which England started in 1846. In twenty years more she had attained an industrial development on a par with that of England in practically every line of manufacturing, in many lines surpassing it. German ambition sets no limit on the progress of the future, for it looks upon the development of the half century as merely preliminary and preparatory.''

These facts are indications of the enormous industrial activity now going on in Germany, an activity which has been developed chiefly since the Franco-German war.

But John Scott Russell was not the first among Anglo-Saxons to appreciate the dangers coming to any nation sluggishly waiting to be forced by necessity to fight for industrial life.

Said Andrew Yarranton, in 1676, in his little book, ''How to Outdo the Dutch Without Fighting:''

''Get a man from Freiburg to put us in the way to make tapes, and to bring over engines for narrow and for broad tapes, with wheels to spin. Send for a man from Dort, in Holland, to put us into the way of treating the fine threads; for a spinning mistress from Germany to govern the little maids and instruct them in the art of spinning, and for a man from Haarlem, in Holland, to whiten your tapes and threads.''

He tells his readers that mechanics' universities have existed in Germany and Holland for many years, and that the only safe plan is now to send to them for teachers. The good fortune of Great Britain, in the earliest appearance of the steam engine in the midst of her people, finally saved the nation, for this century, at least, from immediate pressure in manufactures. To-day, however, all nations have the steam engine, and the same danger is once more arising in precisely the same way: for the Briton has remained conservative, and still insists that no good can come out of a foreign country. Germany, meantime, has come up to her, and is apparently about to outstrip her in the race: simply as a result of a century of wise and steady statecraft, in the development of systematic education and technical training.

But even the Germany of to-day is not satisfied with her position in this race for pre-eminence in wealth, productiveness and civilization, and the following, from a leading British technical journal illustrates at once the fact and the recognition of its basis by British thinkers.

Referring to a recent report, by Professor Riedler and his commission, to the German government, the following remarks are made:

"Professor Riedler takes a bold stand. While practical men have as yet been satisfied with a moderate acknowledgement of their footing on the part of the abstract scientist, and while they have been willing to subordinate applied to pure science; Professor Riedler proclaims that application marks a higher level than mere theory, since it presupposes correct conception and interpretation of scientific principles. Nor is he deterred by allusions to the unscientific pursuit of money-making. The economical side of practical problems is one of the most important and most difficult, and he emphasizes that technical education should teach us how to work for the general welfare with the least expenditure of materials and labour.

The old universities are no longer the seat of universal learning. Technical colleges have arisen, but do not as yet occupy the position due to them. Neither of these two institutions in their present state will be able to cope with the tasks that the twentieth century will impose. Let them be reformed or combined so as to justify the name universities."

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"Although Prussia has done much for the technical colleges, these institutes have not the large means of the old universities; and their professors, who have to demonstrate and assist individually, are overburdened with work. The university professor lectures from his desk, and may ride his hobbies. The State, which shapes and cuts the school curriculum, leaves the university professor a free hand. Some of the universities have broken through their traditional bounds. Agriculture and forest culture have been taken up; there have been lectures on railway construction. Heidelberg used to offer very fair technical courses. But complete engineering departments, such as the Universities of Belgium, the United States, and also of this country, know, have not found a home at German universities."

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"Those researches on which modern progress in a technical respect, which means progress in general, is based, can not be taught by theorists. The old belief in the infallibility of abstract scientific deduction still subsists. A good deal of linguistic and historic ballast is dragged along; whilst the much-praised general erudition is not what it ought to be. If it were, we should not have so much of that shallowness which pervades the educated classes, and of that general readiness to discuss the most serious economical and social problems in after-dinner speech manner. * * * When he (Riedler) speaks of engineers, "*ingenieurs*," he is conscious of the connection of the term with the words genius and engender. He wants engineers to be men of culture."

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"Yet the engineer is the real bearer of civilization. We speak of the stone age, the bronze and the iron ages. Virchow has said that medicine is, perhaps, the only science which can be traced back to the most ancient time. Hardly so, replies Riedler. The history of technical development is older; civilization began with man as a tool-making animal. It is not barren scientific speculation that advances the world. Indian philosophers have not made India a strong, healthy country. Technical progress did not follow the growth of science, but preceded it. Mining is older than geology. The properties of steam were known to the ancients; but engineers devised and perfected steam propulsion and engineers grasped the idea of the conservation of energy before scientists formulated it."

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"Riedler does not believe that any sharp line of demarcation can be drawn between pure and applied science. But he is not wrong when he concludes that the fate of nations depends upon technical and economical progress, and when he asks: 'We admit that we owe civilization largely to technical knowledge; why then does that knowledge not form part of our civilized education?' As regards the ever spreading use of machinery, Riedler does not deny that the immense power placed in the hands of a few by successful manufacture, as well as by trade and speculation, may be for the private and not for the public benefit. But machines advance the great masses in comfort and intelligence. 'Must not an engine driver be more intelligent than a coach driver?'"

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A union between university and technical high school, leaving sufficient latitude for the developement of the latter; continued complete separation of the two? He advocates a union for the accomplishment of which the universities will have to consent to a radical reform. German universities distinguish four faculties: theology, jurisprudence, medicine, and philosophy. The last faculty is the great category into which every enlargement of modern studies has been fitted; and students of languages, social science, mathematics, natural philosophy, agriculture, and also the attached pharmaceutical chemists, all belong to that faculty.

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"The technical high schools have four departments: architecture and building proper; railways, bridges and hydraulic engineering; machinery, ship-building, electrical engineering: chemistry and metallurgy. Riedler proposes to have the four university faculties as before; to segregate two faculties: art and architecture, mathematics and natural sciences; and to co-ordinate the technical departments as stated. He would further suggest that mining, forestry and agriculture and military subjects should be taken over from other institutes, or organized as special departments, 'if university liberty and military discipline were not incompatible.' The new faculty for mathematics and natural philosophy would thus be common to all students whose special training in those branches would be imparted in their respective departments. Chemistry he would altogether transfer to the technical side."*

Thus, in the words of the great English writer already followed in detail:

"To be able to shift the place of our occupation, and find fresh markets for our industry, is not the only preliminary to a successful life in the future. We must be so educated as to be able, without great suffering, to change at any moment the whole nature of our trade, craft, or profession. Are you to-day a chemical manufacturer, skilled in the production of a valuable article of commerce? To-morrow a chemical discovery may annihilate your trade, transfer it into a new class of substance, or a new locality; and if you are either obstinate or unprepared—if your knowledge be scanty, and your views narrow, your business will pass into abler hands. Are you a manufacturer?—a new loom, a new material, a new process, a new mechanical power, may at once deprive your present stock-in-trade of its value, and you will have to begin life again: it is probable that twenty-five years hence neither the implements, processes, nor materials of any trade will bear a close resemblance to the present.

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* *Engineering* London : April 29, 1898, p. 521.

THE ORGANIZATION OF A "COMPLETE AND PERFECT" EDUCATIONAL SYSTEM is the duty and the highest prerogative of the State. The Subject is one of too great and too general importance to be entrusted to private interests or even to private benevolence and philanthropy. It must be made complete and perfect and universal; embracing all the people and all classes in its operation. The provision of such a system of education for the future of their lives is the first duty of the State to its citizens. Not only is it the duty of the State as the primary source of the safety of state and citizen alike; but only the State can insure with satisfactory completeness, perfection and certainty, the provision of the best education for its own citizens. The facts and data for the preliminary scheme of the work can only be secured by the State; the proper adjustment of the relations of the old and the new, of the academic and the technical, of the professional and the industrial departments can only be made by the authorities of the State, and the enforcement and preservation of the ascertained best construction of the system can be only insured by the authority of the State. State education, and state education alone, can insure highest efficiency of the whole educatoinal and industrial and social system, considered, as it must necessarily be, as one great economic whole.

Within such a general and all-pervading system must be, in some manner and to an extent to be determined by systematic investigation, each state for itself, must be incorporated some organization of technical colleges and schools: and this must include professional schools and colleges—universities in some sense—even, we may anticipate, trade-schools and manual training schools. It is to this last group that we are called to give our special consideration and we may now rapidly outline the provisional scheme and its special conditions as a text for later debate and for full discussion by those whose duty it may become to direct its organization and conduct.

Following the plan of our general discussion, we may perhaps adopt some such order and some such titles as these:

(A) The Correct Theory and Method of Organization and Conduct of Professional Schools, generally: the special methods applicable to (a) Professional Schools of Engineering: (b) To Trade Schools: (c) to Manual Training Schools: (d) to mixed Professional and Educational Curricula.

(B) The sub-topics under this subject are:

(1) In the technical high school what properly determines the form and extent of its technical and other courses?

(2) In such schools, what should be the extent and character of what may be termed the distinctive

and essential entrance requirements? What the non-essential requirements?

(3) In the technical college, what should be the nature and extent of these two different classes of demands? What courses should be offered in response to the demand for technical instruction from people whose sons must go directly into business from the lower schools if they can not obtain a directly useful technical training?

(4) The professional engineering school. now being evolved—the distinctly professional school, having the same position and purpose as, in other professions. the law and medical schools,—must, soon, if not at once, require definition and delimitation from the academic colleges. What should be the entrance requirements?

(5) To what extent should the existing views and traditions of the people generally, and the prejudices of the academic teachers and monastic scholars, be deferred to, in the construction of the curriculum of the professional school of engineering, in which, as must be assumed, the work is to be professional training and not, in the accepted sense of that word, education?

(6) If a body of academicians controls the faculties of professional schools, what course should be taken to secure independence from inexpert direction and to insure the management of professional institutions by professionally expert faculties?

(7) Assuming that it is obvious and is admitted that the form and extent of a professional course must

be simply that which is demanded by the character of the work of that profession, and that it may be taken for granted that students entering such institutions, will, as a rule, if not invariably, have sufficient intelligence and judgment to secure just as much of liberal education—of *real* education, in the accepted sense,—as possible, what should be the length, the extent and the limitations of such courses *in the distinctively professional school?*

(8) In such institutions, what other than professional work if any should be offered? What entrance requirements would suffice? Should the policy be that of a wide range of non-essential entrance requirements and high academic culture, with, necessarily, few students; or should the entrance requirements be restricted to characteristic and essential introductory work *with*, presumably, unobstructed freedom of entrance of all classes and conditions of men; *provided* only that the poorest of them has attained competence in preparation in the essential requirements for entrance upon professional studies, as taken up at the beginning?

(9) In the technical high school, and in the technical college of the more common sort in this country, in which some educational work is usually necessarily offered, where should the lines be drawn in respect to entrance requirements, and where in constructing the courses themselves, in such semi-professional schools?

(10) What are the similar conclusions respecting trade schools and what respecting the manual training schools now becoming common in our cities?

(11) How shall we classify all these various, as yet undefined. courses and schools, in order to secure some definite principle of organization and operation?*

With no complete and perfect system of general education and training of any people yet organized, with even the educational department of the German government somewhat at sea regarding the best methods of completing and perfecting its work and with no attempt, even, yet, made in our own country to complete and perfect a system adapted to the necessities of the people and of the nation as a whole, this whole scheme remains open for discussion and elaboration. The initiative properly is with the educators of the country and in each state; and the Boards and Bureaux of Education should supply facts and data and obtain reports from our own and foreign states giving the history and outcome of attempts to intelligently put in practice the great enterprise outlined by Mr. Russell and inaugurated in the United States by the legislation of Mr. Morrill and his colleagues and successors in the work.

The work is to be done, obviously, by adding to and uniting with the existing academic educational system all those no less essential branches of technical education and of trade and professional training which are required to realize Milton's Idea—the "Complete and Perfect Education."

The topics above presented are treated in a somewhat cursory manner, but yet with sufficient detail to open the discussion of the subject, in the following outline.[*]

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*Circular of the Secretary of the Society for the Promotion of Engineering Education, 1898.

THE CORRECT THEORIES AND METHODS OF ORGANIZATION AND CONDUCT OF PROFESSIONAL SCHOOLS of whatever sort are in essence the same. The courses of instruction in engineering, in trade, in manual training schools are similar in general character in their characteristic features; they are properly organized on similar principles and by similar methods and must have their relations to the academic schools, whether high or low, primary, secondary or collegiate, determined by the same principles. These principles, on the other hand, are by no means identical with and may not even resemble, those dictating the construction of the courses, the details of curricula, or the entrance requirements of the academic school.

The Ideal System of Planning the Professional School would seem to be the following:

(1) Ascertain what are the needs and demands of the profession to insure the highest efficiency of its practitioners, the best result of its operation as an element of the industrial system of the Nation.

(2) Determine just what portion of the professional training is practically and appropriately to be demanded of the professional school. Take this scheme, properly scheduled, as the reasonable and proper requirement of the student entering the profession as a

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[*] This line of discussion was suggested by the necessity, recently, of presenting the subject to the Board of Trustees of Cornell University in reply to the question: What is needed to make the entrance requirements of the courses in engineering the equivalent of those in the academic courses.—Report of the Director of Sibley College to the Board of Trustees of Cornell University, 1898.

novice, with his strictly preparatory education completed, prepared to commence the acquirement of the art of that profession by practice and experience.

This scheme presumably should include a knowledge of the pure sciences underlying the art to be pursued; for such studies can not reasonably be expected to be acquired in later, professional, life. It must include so much of the applied science of the chosen vocation as can be safely and successfully incorporated into the curriculum of the school; for it is this which constitutes the claim to rating as professional. It should include such necessary and such desirable elements of the college curriculum as are not fairly to be expected to be possessed by a novitiate and which are needed to permit the acquirement of professional knowledge.

The complete scheme of studies for the technical school of this higher, professional, class, obviously, thus comprehends these three main divisions: (1) as the ultimate and final preparation for professional work, certain distinctive and professional branches which are recognized as appropriate and needed for professional success; (2) certain branches of pure and applied science which are essential as preparatory to, or as needed accompaniments of, the distinctively professional studies; (3) certain accessories, the possession of which is found, by professional experience, to be prerequisite to main or incidental lines of work and progress toward the idea of the profession.

(3) The plan of the curriculum of the professional course being thus by exact methods prescribed

and limited, it must next be ascertained to what extent the educational institutions to be drawn upon can supply the needed preparation for entrance upon the proposed course. A statement of such work in preparation as may be reasonably expected constitutes the proper system of entrance requirements and the only appropriate demand for the professional school.

If it is found impossible to secure elementary preparation for entrance into the course as planned, it will be found necessary, as has constantly occurred in our own schools, to incorporate some non-professional work into the professional scheme; but this means simply that the professional school is compelled to do work outside its province. Should it prove, as has usually been the fact in this country, that so much non-professional work must be performed in the professional school as to compel excess of load, the surplus is necessarily left out and the student is compelled to defer professional study of importance until actually entering upon professional practice. Such a mongrel course is now illustrated more or less by practically all engineering schools, and it may be a generation before they can be raised to a professional level.

Meantime, all are endeavoring to gradually raise the professional scheme of instruction and even to provide opportunity for the advanced student to secure accessory and closely related and important instruction in law, economics, the finance of engineering and economics of manufactures; at the same time, circumstances permitting, proposing to restrict the specified preparation for the professional school to essentials, leaving to the candidate for admission the decision of the question just how far he can afford to give time, money and strength to the pursuit of earlier academic studies.

The fact is that with every technical school and especially with the professional school in the department of engineering, the entrance requirements should be made just as few, just as fit, and just as precise in adaptation to the courses to be taken up as is by any means possible. The nature of the professional course to be offered, and the sequence of primary studies with its special courses, determine the proper requirements for entrance. To increase entrance requirements by introducing those which do not furnish suitable introduction to work to be taken up is to deprive deserving men, usually the most deserving classes of young men, of the right of gaining a scientific knowledge of the fundamental principles of their chosen profession, or art, or vocation. To raise requirements for sentimental reasons, simply to make entrance into such courses as difficult as into others, is, in the opinion of every person familiar with the equities and the facts of the case, a crime against the people, and especially against the "industrial classes," the special care of whom is made, by the fundamental law and by the charter of the Land Grant College, its primary duty. "Procrusteanizing" is bad in all departments; but procrusteanizing in any university seeking to adapt itself to the needs of a people, including the "industrial classes" as well as the cultured, is an educational blunder, a political mistake and a crime against those classes of society which it is the great purpose of such a college and of its founders no less, to give most effective aid. A famous engineer, at the head of a deservedly famous engineering college, discussing this subject from the point of view of the practitioner, as well as of the educator and professional expert—all of which capacities he illustrates in a rare and admirable degree—writes:

"I fear that our preparatory schools are under influences, if not inimical indeed, certainly unfavorable and unsympathetic towards the preparation that should be given to students entering scientific professional courses. The schools now furnish much matter upon which so called 'counts' are based, which could be easily supplanted by other matter, quite as useful in developing the thinking power of young people as any subject they now exact; whilst on the side of professional training, we must demand subjects that should not be taught in the college and yet the schools do not provide for them. I believe the majority of young men entering the college of engineering have to obtain special preparation outside the schools. In many, even large, cities, plane and spherical trigonometry, solid geometry and perhaps advanced algebra are rarely taught. A student now in college, was refused instruction in solid geometry and plane trigonometry because the school could not afford to hire a teacher for him alone. If this is the usual fact, higher education is only within the reach of the wealthy classes, and intellectual scientific progress is dammed at the outlet of the public schools.

"It is indeed strange that, in a country so essentially industrial as is ours, all the efforts of the public schools towards higher education seem to be confined to the promotion of old academic courses and literary professions. Yet the study of the classics is exceedingly backward with us; and, in spite of all the drawbacks from this state of affairs and the often narrow-minded discrimination observable against their students, the schools of engineering in this country are generally the best of professional schools, and some of them have no superiors, even as to intellectual accomplishment, on either side of the Atlantic." As elsewhere remarked by the writer:*

"It is as essential that the engineer familiar with this branch of construction should plan and direct the courses of instruction in engineering as that the student should be instructed by an engineer. Experience shows that it is a decided advantage that every subject taught in engineering schools should, as far as practicable, be taught by engineers, or by specialists practically familiar with engineering and its applications of their subjects. We even find great advantage in securing instruction in applied mechanics from members of the profession having a talent and special predilection for that subject. The absurdity of estab-

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**Technical Education in the United States; its Social, Industrial, and Economic Relations to our Progress.*—Presented at the Chicago Meeting of the American Society of Mechanical Engineers, and read at the world's Engineering Congress, July, 1893 Trans. A. S. M. E., Vol. XIV, No. dxliv.

lishing engineering schools with non-professionals at their heads has slowly come to be recognized to be as great as that of the custom, formerly general, of putting a clergyman, as such, simply, at the head of every college, the folly of seeking to construct an engineering course to be taught by non-professionals is not less patent." "The organization of any professional school with any other than a professional expert at its head has come to be recognized as eminently absurd and dangerous. Eminent professionals at the head, and talented men *practically experienced* on the staff, are the primary elements of success in an engineering, as in any other professional, schools: and a no less important element of success, perhaps, is the placing of specialists in charge of special lines of engineering work. This is now always a feature distinguishing the larger and the better classes of technical schools and colleges. A baby should not only be 'nursed by one who loves it,' but by one who knows what it wants and how to supply it."

In detail, we may perhaps summarize the points of discussion as below, following the order already given:

(1) In the Technical High School, the form and extent of its technical and other courses must, in the now usual case, be settled by the conditions characterizing the location, and by the character of the adjacent population. As a rule its pupils must come from the same class of schools as those which furnish the candidates for admission to the academic schools for youth of similar age. This means that the technical

courses, which are commonly largely mathematical, must be started at that point at which it is found practicable to secure satisfactory preparation in the schools. The science work must be similarly adjusted and this commonly means that it must begin in the technical high school itself; for it rarely happens that any real scientific work can be offered in the next lower grade of academic or manual training school, and, even where attempted, it is too generally the fact that it is so ineffectively performed that the pupil must begin in the high school to unlearn what he has been taught, rather than commence any real work of this sort. All that can be said of the general case is that all that can be had from the lower grade of school should be secured and thus here, as in all grades and schools, the greatest possible economy of time and labor secured and the earliest possible beginning made in technical work.

In addition to the technical and semi-technical scientific work of the course, the essential elements of the academic education of the average citizen should be provided, and, in addition, an effort should be made to give some instruction in at least one modern language. This, for the purpose of the average engineer, is best made the German language and ts technical literature; while the architect usually prefers the French.

The manual training or the trade instruction should be condensed into as continuous periods as practicable and it will be found to have the double advantage of giving at once some useful and practical knowledge and that added physical vigor which assures the power of making the most and the best of the mental powers. One has only to visit the U. S. military and naval academies to witness, in perfection, this peculiarly desirable gain.*

In each city and town, the technical high school should be adjusted, in extent and character of its courses, to the particular vocations which are most characteristic of the place and, in fact, in many, perhaps in most, cases should be made, if not a regularly organized trade school, as largely accessory to the requirements of the principal vocations of the place as practicable. In large cities, where several such schools can be perfectly well organized and are really needed, a system of trade schools may be substituted for the technical high school, in each of which schools some important trade may be systematically taught, with all the special scientific and related courses appropriate to such technical courses and schools. Germany admirably illustrates this idea and there every city sustains carefully planned trade and technical high-schools directly adapted to the needs of its people.

(2) The distinctive and essential entrance requirements of such schools, as already remarked, must be as high as circumstances permit. Their precise form can only be stated when the conditions of the educational system of the place are known. The essen-

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* See *The Outlook* for August 4th, 1898, for excellent accounts of these features of those oldest of our technical schools—with the exception of that veteran among the technical schools of the United States, the much deserving but never fully appreciated Renssalaer Polytechnic Institute of Troy, New York.

tial requirements are those which lead directly into the work of the school; the non-essential—professionally speaking—are those academic studies for which time and place can be found in addition. No definite limit exists to their extent and only the greatest discretion will secure the highest efficiency of the technical school courses as a whole.[*]

(3) In the technical colleges, these requirements and the courses adopted, in any consistent system, should have the established character and altitude of academic college work in so far as they are not distinctively professional. The technical high schools and the trade school, for example, would presumably demand mathematics sufficient to permit the taking up of higher algebra and geometry; the technical college would demand sufficient to allow of entrance upon the higher mathematical branches, as analytical and descriptive geometries and the calculus; the objective being early entrance upon the study of the subject which constitutes the spinal column of the whole technical curriculum—applied mechanics.

Laboratory work in the sciences of chemistry and physics and extensive courses of instruction in draughting and in machine-design, with as much trade instruction as can be provided, will constitute the characteristic studies; while the modern languages, French and German, at least, will come in as non-technical but essential elements of the curricula. In many cases, law, economics and mercantile practice can be brought in to supplement the-purely professional work of the engineer, the architect or the textile designer and the practitioner of industrial art of whatever sort. The primary and most important point is the securing from the preparatory schools of as large a preparation in mathematics and the sciences, and in modern languages and literature, in addition to the lower recognized standard academic studies, as can by any possibility be obtained.

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[*] See the paper by the writer, "Technical Education in the United States," published in the Transactions of the Am. Soc. Mechanical Engineers, 1893, as read at the World's Engineering Congress of 1893 at the Columbian Exposition, Chicago, Ill., in that year, especially pp. 4, 5, *et seq.*

The courses to be here provided for the satisfaction of those of the people whose sons must go at once into business on leaving the high school or the college should be such as are most certain to prove valuable as best promoting the interests of such youth by effectively increasing their capacity for successfully and usefully passing on through "the sequel of their lives." It is often practicable to "kill two birds with one stone," sometimes a dozen, by teaching such studies and introducing such methods of teaching applied science and languages as will at once furnish education and technical knowledge and training. In fact, one supreme advantage of much technical study is that it provides at once the gymnastic training of the academic school studies and valuable knowledge of a professional character. General Walker, the late President of the Massachusetts Institute of Technology, always claimed that the technical college, properly organized and administered, possessed decided advantages, for all youth, over the purely academic school, in that it gave at once gymnastic training in all essentials and useful and safe insurance against misfortune of the possessor of learning without such knowledge. He thought that the learned man, simply and as such, was never a wise man.

(4) The Professional Engineering School, as an accompaniment, in the educational organization, of the academic college, as an element of the modern university, like the law school, the medical school and the school of pedagogy and the school of theology, would, in the "complete and perfect" organization, be an institution in which, as in the law school, professional courses would be taught, supplemented in the school itself by such courses in applied sciences and in technical language and literature as could not be fairly expected to be provided by the academic schools of the university or the common academic college. The entrance requirements, as later stated more fully, should be such as can be met either by the preparatory schools or the other departments of the university, without demanding too much of the matriculate, and can only be finally adjusted when experience has shown just what may be safely asked of those other schools and departments. The reports of the committees of the American Society for Promotion of Engineering Education show what is the situation, in this respect at present, in various parts of the United States. It may be safely asserted that it will be many years before it will be practicable to adopt uniform requirements for all, or even to comply with the ambitious demands of

the academic schools regarding academic non-professional studies—preparatory or other. We will presently consider these points at length.

(5) The extent to which the existing views of the people and current tradition in the schools and the prejudices of uninformed and unthinking academic teachers and of the monastic scholars of the community are to be deferred to is a question of greater importance that the professional commonly either believes or admits. Whatever this extent of deviation from what the practitioner often thinks the desirable organization and curricula of the professional school, it must be remembered that we must, probably, always be dependent, more or less, upon the fairness, good judgment, and kindly assistance of the academic teacher, that public opinion will always be largely moulded by the non-professional and that it is incumbent upon every member of the profession—and most of all upon all who are engaged in the upbuilding of the modern system of "Miltonian," of "complete and perfect," education, which shall include both the academic and the technical curricula—to so present the case as to secure in as full amount as possible, that fair and kindly discussion and that unprejudiced consideration which only can bring about that condition of public opinion, and especially of the most intelligent of public phases of opinion, upon which the people must ultimately rely for the fittest development of the to them vitally important changes of system in our modern education, and for its final complete adaptation to the highest needs of the community.

It is, in any event, the duty and the rightful privilege of the professional expert in technical education, in consultation with the practitioner, to construct the curriculum and to administer the technical school or college, of whatever form, and in its development he must, in the performance of a duty to the public as well as to the profession, carefully follow that golden mean—in deciding between the claims of the scholar and those of the practitioner—which shall insure prompt construction of the system to be developed and give it best insurance against injury and embarrassment by the larger power and influence of the academic teacher prejudiced against the Miltonian idea or ignorant of its merits and of the needs of the people.

(6) The control of the technical and of the professional school by non-professionals, whether officially, through public officials, or unofficially through public opinion, is one of the most dreaded dangers in the development of the forms of practically useful education regarding which Aristotle, Milton and John Scott Russell have so eloquently written. The course to be taken in avoidance of such danger is obviously to see that public offices capable of being employed to injure the interests of the people in this direction are filled by men at once familiar with the subject, practically interested in the development of the best education of the people for the people's work, statesmanlike enough to see the bearings of the matter upon the best and highest interests of the nation, and strong and conscientious enough to do what they can to sustain

and promote a truly scientific system of public education. Germany has produced such men; the United States should be able to find an even larger and better class and to give them their opportunities.

Further, it is important that public opinion and the opinion of the academic educators, particularly, be formed by thoughtfully presented facts and arguments and especially by making known the marvelous gains effected by the German people through partial and imperfect development of a Miltonian educational system by their statesmen during these last generations. An enlightened public opinion, given practical expression by wise statesmen, will inevitably bring about the desired end.

(7) The extent and limitations of the curriculum of the distinctively professional school where students entering may be expected to have secured as extensive a liberal and academic education as their time and means, or the means of their parents, permit, should obviously be such as would be obtained by eliminating from the existing curricula all those non-professional studies which can be secured in the academic college, as the modern languages, the pure sciences and the higher mathematics, and substituting advanced professional work not previously attainable. Of this there will always be an ample amount available. When the limit is at last reached, the reduction of the professional course, until it is brought down to a length which will perhaps permit the graduate to enter upon his work and begin to earn a living soon

after coming of legal age, will be an advantage of enormous value to him. Could he be graduated at twenty-one, the country would gain greatly; could he even always take his place in the ranks of his profession at twenty-three or four, it would be a gain; for, although many graduate from our technical schools at that age, they are seldom as fully and symmetrically educated, either academically or professionally, as is desirable.

(8) In these highest and most distinctively professional schools and the question is one which applies to all professional schools, law and other, as well as those of engineering—it is asked: What shall be the extra-professional curriculum, and what shall settle the boundaries of the school? Shall it make its requirements and its course as high as practicable, thus restricting numbers and, in a certain sense, creating an aristocracy, a professional "four hundred;" or shall the requirments and the course, or that part which leads to the professional degree, be held down to the lowest acceptable plane and thus the largest possible numbers of candidates for entrance into the profession be allowed to practice with the endorsement of institutions of learning?

This is a matter of such supreme importance, to the nation as well as to the profession and to the individual, that its decision must be most deliberately determined; and only time and experience can settle it. Possibly the existing method may continue in operation. To-day, each engineering school fixes its own course and states its own requirements, and the usual fact is that the smaller schools hold lower, the larger schools higher standards; adjusting them to the location, to the conditions of the educational system of the place and time, in accordance with their own judgment of the wisdom of the course taken. This results in the provision of a variety of schools of engineering, as of other professions in which standards are high or low, courses more or less purely professional, and diplomas having correspondingly variable values—very much as among the coinages and currencies of different nations. The standing of each and its reputation is usually well-recognized, however, and the outcome is the provision of technical education of considerable range in grade and quality for the most fortunate and for the least fortunate of aspirants alike. Each professional school, adapting itself to the situation in which it finds itself, it is possible that a maximum amount of good is done with a minimum amount of injury to the profession, to the schools and to the country.

It is important that the schools should do all that they possibly can to elevate the standing of the colleges and the professions; it is still more important that artificial impediments shall not stand between the poor but talented, the ill-educated but honest, earnest and ambitious and naturally well-fitted youth, and their service of the nation in that vocation for which nature has particularly fitted them. The range lies between that low plane of professional training which verges on quackery and that high standard which restricts professional instruction to the classes having ample time and means, and able to secure the best academic education and the most liberal culture previous to entrance upon the study of professional matters and into the purely professional school of highest rank. Very probably the great universities and the few leading professional schools in sections of the country where general education is farthest advanced, and particularly in the largest cities, may find it to their interest, and to the interest of their patrons and the public as well, to steadily raise their standards until their technical schools are professional schools purely, with all preliminary work and much of their elective work, if they offer it, provided by the related academic schools and colleges; while the less fortunately situated in this respect may offer curricula intermediate between that of the highest university schools and the lowest that can, in any degree of fairness, be accepted by the guild as giving right of entrance, into the work of the profession. Within this range many schools will adjust their curricula in such manner as to meet the requirements of the place and time; neither adopting highest culture and loftiest schedules of study with minimum numbers of students, nor that minimum range of work which is unjustifiable even by resultant increase to a maximum in the numbers admitted and graduated.

(9) The technical High School is usually necessarily a semi-professional school. It must at once educate and technically train its pupils. It is neces-

sarily a part of the general school system and must receive its pupils from the lower grade schools of its location. This means that, in this case, the entrance requirements must be such as are fixed by the necessity for arranging a smooth and unbroken line of studies from the primary on into the higher schools, and entrance into the technical high school will be given through substantially the same sort of general preparation as into the academic schools, except that the scientific and mathematical work will constitute the main elements of such preparation, rather than the classics or even modern languages and literatures. The semi-technical curriculum is constructed by leaving out of the curriculum of the corresponding grade of purely academic school all really unessential work and substituting for it technical studies and their accompanying laboratory work, draughting and shopwork. The latter, indeed, may perfectly well, in this case, be given in time taken from the ordinary playtime of the pupils; since it affords exercise as well as—to those likely to choose this schooling—pleasure and instruction combined.

(10) The Trade Schools and the Manual Training Schools are subject to the same remarks. They must usually be incorporated into the school system and must thus be made an integral part of that extended course of education which must begin with the youngest children in the community and steadily and effectively progress through intermediate to the highest grades reached in each line of study and work. The

distinction between the trade school and the manual training school must be carefully noted, however. The former teaches the precise methods and the exact limitations of the trade; giving sufficient practice in its manipulations to make the pupil expert in the use of the tools of the trade and familiar with its special formulae and processes; turning out young men having, in addition to the technical knowledge given by this systematized apprenticeship, a good knowledge of the sciences, so far as specially applied in the trade taught them, and, beside, the elements of a good secondary education of the most practically useful sort. The manual training school, on the other hand, is usually one in which a more youthful class of pupils is taught skill in the use of their hands and brains, and, incidentally, the use of the tools of the familiar vocations. The latter may grade upward into the former, as the ages of the pupils, are greater, by imperceptible gradations. The trade school is properly an independent school in which a city teaches the vocations into which its citizens most largely enter, and for the products of which it has largest market and highest reputation. The manual training school is a natural and proper adjunct to every common school system, in city and country alike.

(11) The Classification of these various technical and professional schools is easy when a sufficiently broad view is taken of the field and of the economic relations of the schools and their work to the life and work of the nation. When the fact is recognized that

every state and every nation owes to its people the organization of a general system of education—not abstract and ideal, not fitted to the purposes of the well-to-do citizens solely, not planned from the point of view of the older academician or fitted into the ancient monastic scheme—a system adapted to the immediate and practical needs of a great body of civilized people endeavoring to live and work and to enjoy the privileges of modern civilization on an average income of between six and seven hundred dollars a year, for a family, in the settled portions of the country; when this is understood, the question finds easy solution—in words. The difficulties of securing the inauguration, in even our enlightened country, of such a system, in the face of long-standing prejudice, of existing and established curricula of the ancient and cloisteral type, of indifference on the part of politicians filling places belonging to statesmen, of ignorance, on the part not only of the average citizen and voter, but even on the part of the intelligent men of the country, very few of whom have given time to investigation, or thought to this most important of economical subjects, are beyond estimate. These difficulties, however, are certain to be in time overcome; for their removal is essential to the progress of our country in its great career.

The classification may, perhaps, take some such form as this:*

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*This scheme was substantially constructed as here presented by the writer when, as member of the New Jersey Commission for devising a Plan for Encouragement of Manufacturing Industries in that State and as Secretary of the Commission, he prepared for the Commission such a scheme

See report of New Jersey State Commission; Trenton, 1878: also Sibley Journal of Engineering, June, 1892, "The Demands of the State;" also the Trans. Am. Soc. M. E., 1892, Vol. xiv.

(a) A common school system of general education providing the elementary studies of a good English education; perfecting the pupil in the arts of reading, writing and arithmetic, at least, and with so much of the most essential primary work in language, geography, etc., as space can be found for, without reducing the vitally important work to inefficiency. This system should be adapted to the needs of all classes.

(b) A system of special adaptation of primary instruction to the needs of children who must become skilled artisans and who can not be kept in school by their parents longer than during the period of their growth to that size and age at which they can be made to assist in the support of the family. Such a system may perhaps prove to require special adaptation of text-books to the purpose, in which text-books the terms of the trades, and reading matter giving accounts of industrial processes, may be introduced.

(c) A system of trade-schools in which general and special instruction may be given pupils preparing to enter the leading industries; in which schools the principles underlying the principal vocations of the locality are to be taught and the essential actual manipulations, of the trades are to be illustrated and taught by practical exercises until the pupil becomes expert.

Thus, the Germans have be-sprinkled all over their country schools of carpentry, blacksmithing, weaving, bleaching and dyeing, forestry, agriculture, etc.

These schools should be established in every city and town in the state.

(d) Polytechnic schools should be incorporated, formally and with system, into the great educational scheme of the state and of the country, in which higher work in the applied sciences and, usually, some trade or professional instruction should be offered students whose circumstances are such that they may be given an education extending toward the years of maturity and whose talents and inclinations lead them to select technical school work as introductory to their later practice of the industrial arts.

(e) Technical schools and colleges, professional schools within the colleges and universities, in which the highest professional instruction in the applied sciences and in the scientific basis of the professions may be offered those who are permitted by rare good fortune to secure a good, a liberal, education while preparing for entrance into the professional school and upon their chosen line of life-work.

(f) Such a bureaucratic system of supervision and conduct—presumably by the state, acting through experts in all branches of educational work, and all imbued with the Miltonian idea—such as will insure symmetry and efficiency, of the whole great structure of education of the people for the life and work of the people.

(g) In the United States, the work of the several states should, it would seem, be correlated by a a great central, a national, organization, a national university, presumably, in which and to which all lines should converge straight from the most elementary of the primary departments and schools, through the whole system of academic and technical secondary schools and state colleges and universities, and which should thus serve at once as a source of authority and of instructing talent of the loftiest character, providing men of genius and giving grandest educational advantages to all lower grades; giving the level up to which the tide of culture may rise in attaining the highest possible altitude, and serving, further, as the ultimate goal of the great minds of the nation.

(h) National bureaux of education having enlarged powers, wider duties and grander opportunities of engaging in the task of instituting and promoting systematic and general education, such as Milton would have approved, and serving as the great advisory and directing agents in the permanent task of maintaining and improving the symmetry and completeness of the whole national, state, and local systems of general and special education.

The Subject of Entrance Requirements to the engineering colleges, their relation to those of academic colleges and departments, and to the educational system of the state, as well as to the demands of the profession—the practically and necessarily controlling consideration with any such institution expecting to succeed in its work—has come up for discussion in a number of ways recently. In issues of technical journals, of late date, there has been some serious criticism of the technical institutions of these classes on the score of lack of consideration, in the fixing of entrance requirements, of the status and of the best interests of classes of people directly concerned in their development. Individual comment, by members of the profession of engineering, by practitioners among manufacturers, by employer and by employees in the mechanical industries, and the reports of foreign expert critics have also indicated the fact very clearly that there is, to-day, no very well-defined consensus of opinion among those who should be most competent, most interested and of highest authority in the matter of the building up of a system of technical and professional education for the special advantage of the industrial classes and interests of the country and for the elevation of the vocations related to them toward a higher plane of efficiency and achievement.

Thus, the editor of a leading and influential journal, one of the ablest in its department, remarks:

"It is all very well to say that a man thoroughly grounded in general principles can attack any problem successfully and that the purpose of education is to teach men to think, and not to merely fill their heads with useful information. All this, in a broad sense, is of course true; but, at the same time, the object of most young men in attending an engineering school is, we think, not so much the development of their minds as the equipment of themselves to earn their livelihood; there can be no doubt that the course of study should be directed to the latter object, and that the student should be familiarized with the sources of those data and practical formulas which have been put in shape for quick use."*

And, again, it is remarked:

"We are fully persuaded that the spirit of the old, so-called, liberal education—whose chief purpose is mental discipline—has been allowed to have altogether too much influence in modern technical education. A modern engineering course can not be pursued without its affecting the mental discipline, and many strictly technical subjects are just as valuable, from that standpoint, as those which are lugged in for that purpose alone. The mental discipline is, in other words, a necessary incident to the work, and no special effort need be made in that direction. The feature requiring attention is not, then, in our opinion, the discipline of the mind, but the reduction of general principles to the point where they can be applied to use."

The view of another well-known writer in an entirely different field follow the same general line, and such a statement as follows is only the sentiment of many minds among liberally educated and able men, given form by a writer of recognized acumen and fair-mindedness:

"Important branches of education are now regulated through what is called a 'conference' of colleges, looking to uniformity in entrance requirements. The advantage of such a system is open to much question, especially as respects a department in what may be called a formative or plastic stage of development, as English at present unquestionably is. If its end be to bring about a species of combination in restraint of trade among the institutions of advanced education, so that no one of them shall secure more than its share of the business by putting the standard for admission lower than the others, it presents an aspect of the educational problem in no way edifying. It is again a case of quantity as opposed to quality. If, on the other hand, the result of the 'conference' is to establish a rigid uniformity of requirement, it may safely be assumed in advance that it will be a uniformity of the pedantic and the commonplace. *Non tali auxilio*—no real advance in the higher education will come in that way."*

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* *American Machinist*, December 9, 1897.

The position which is held to-day by the foremost professional schools of engineering in the United States is perhaps best indicated by the reports of professional critics and experts from Europe, and especially from Germany, some of which it may be remembered were quoted in the last of this series of Director's Reports. An American writer on this subject has recently made the following statement:

"After considering these chaotic entrance conditions to the professional colleges of law and medicine, it is refreshing to turn to another, in which, with but little pretension—with modesty and deprecation, rather—a model has been set which all other professions will, in the end, surely follow.

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*Charles Francis Adams in *The Nation*, December 9, 1897.

"The engineering profession to-day is, upon the whole, the best educated in America. While there may be a smaller proportion of highly trained men, there is also a far smaller proportion of poorly trained ones than in either medicine or law. It may seem strange that that profession which comes less into immediate contact with the general public should be, upon the whole, more highly trained than those which touch so closely the pecuniary and physical well-being of every one. But the reason is not hard to find. The engineer is judged more by his peers, while the lawyer's or physician's success is dependent very largely upon the public. The capacity of the engineer must invariably be made apparent to men of affairs and ability, while the lawyer or physician is judged, for the most part, by those who are incompetent to determine his real merits.

"Undoubtedly, as the years go by, more rigorous requirements will be demanded from the engineer, as from the lawyer and physician, but I do not believe that they will ever be very great in extent, save as new methods of teaching are developed, and these will require ability and capacity rather than time. The engineer may enter upon active life at the age of twenty-four or five at the outside, fully grounded in the principles of his profession. No gap is left in his education between the high school and his strictly professional course, but the one grades into the other in an harmonious way. Though he graduates with the commonplace degree of Bachelor of Science, it represents, on the average, more college work than does that of Doctor of Medicine.

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"The most earnest students that we have are those of the professional schools. A distinguished teacher of engineering has said: 'It is unquestionably a fact that the engineering students of our colleges do more and harder work for a degree of equal grade than do the students of other departments.' As a teacher of medical science I know that the average medical student does fifty per cent more work than those of like capacities in the undergraduate arts courses. There can be no denial of the fact that the most earnest students are those who seek knowledge as a direct means of success in life rather than for the mere pleasure of its possession." *

"Quite as good exercise may be found in getting somewhither as in walking around the square," and the question of the relative educating value of the older standard educational scheme and the comparatively recently admitted curricula of the non-classical and the technical schools has largely dropped out of sight. Experience shows that the graduates of the more scientific and less monastic and literary courses are, in fact, in no degree inferior, and suffer in no way in the comparison, beside the product of the school organized on the plan of the mediaeval schoolmen. Every exercise in applied mathematics, for example, gives at once the desired gymnastic training and a new power of accomplishment of useful tasks. Each lesson in physical science, or in a modern language, gives the training and discipline of the gymnastic schools and at the same time, and with even added efficiency, promotes the power of acquirement of learning, while it makes the learning thus gained take a continually more and more productive and effective form. All scientific and technical schools have curricula which presuppose, and usually demand for entrance, some adequate instruction in the high schools in all the essential liberalizing classes of literary and historical work, if not in the classical studies themselves. The whole course, trend and purpose of such schools and colleges must invariably and with peculiar effectiveness insure not only the acquisition of "useful knowledge," the *bete noire* of the ancient régime, but also very effective intellectual gymnastics and an increased power of retaining and utilizing knowledge such as only that peculiar interest which comes of actual use can confer.

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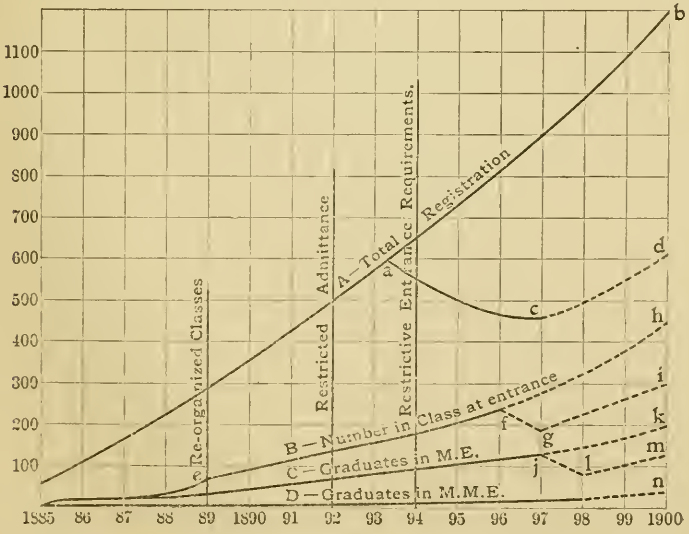
* S. W. Williston in *Science*, December 10, 1897.

In the opinion of many of the ablest and most authoritative members of the profession, the process of raising entrance requirements has already gone to far, and the result of carrying the process further, for purely sentimental reasons which do not appeal to the people who desire to send their sons to such schools, will be to seriously cripple institutions of this kind in the work of aiding the industrial classes and of complying with the spirit as well as the letter of the law making the "leading objects" of these schools and of the colleges to which they are attached that of providing technical instruction for those who can not, because of lack of time, of money or of talent for literary work, take the older college courses, and with whom the alternative lies between going into technical schools and going directly into business, when leaving the high schools or earlier.

As it is, in the opinion of these members of the profession, we lose many opportunities of helping young men, who now go directly into business, while, were the requirements made, as they would say, more reasonable, they would come to secure a good scientific training for their chosen work.

In illustration of the sensitiveness of the average technical college to changes in entrance requirements and consequent changes in its relations to the preparatory schools as now customarily conducted, ignoring demands of any other than academic colleges and universities, it will be instructive to study the accompanying diagrammatic representation of the working of such a change compelled by the increase in numbers of students beyond what was at the time thought a limit for good work and of suitable equipment and accommodations.

The accompanying diagram presents the statistics of growth of Sibley College from 1885, the date of its organization upon its present basis, to 1897-8, and the presumptive changes to A. D. 1900, assuming no further modification of the conditions of entrance and of the course itself, meantime. Referring to the diagram: Following the upper line, *A*, we observe that the total registration began rising instantly upon the establishment of an engineering course, from about 100 in 1886, to 200, nearly, in 1887, 300 in '89, 400 in '90, 500 in '92, and to 638, in the year terminating June, 1894. At this point, the non-professional entrance requirements were raised by demanding an additional year of higher mathematics; thus permitting the freshmen to take up analytical geometry and the calculus, and the sophomore class to study and complete applied mechanics—a change which proved of enormous advantage in improvement of the course of study. But the registration necessarily at once dropped off to lower figures, until, in the year 1896-7, the registration of undergraduates was less than 500.



STATISTICS OF SIBLEY COLLEGE, 1885–1900.

On the other hand, the numbers of the graduating classes continued to rise until this change had its full effect, and numbered 125 in June, '97, but will not exceed, probably, 90 in '98; after which date it may be expected to again resume its upward march. Curves *B* and *C* show the numbers of these classes at graduation and at their entrance into the College.

The line *a b* indicates what might have been expected, had no such radical and unprecedented increase of the demands at entrance been made. The College would, at its then rate of growth, have attained a census of 1,000 students in 1898 or 1900, possibly 1,200 in the latter year. Numbers were then restricted by thus cutting the expectant entrance-class in half and its numbers fell as shown, and the dotted line, *c d*, indicates where the figures will probably reach, at those dates, as now thus reduced. Similarly, the lines *f h* and *g i* show what numbers were promised, between the specified dates, under the one, and what under the later, arrangement. The lines *j k* and *l m* show what should have been and what actually will probably be the magnitude of the graduating classes, in 1898 to 1900, inclusive. The line *D* indicates the number of students taking the Master's degree. The peculiar "hump" at the date '89 indicates the effect of the unsuccessful attempt to restrict numbers at that date by limiting the number accepted.

Just what is to be considered the real balance between advantage and disadvantage due the noted elevation of the entrance requirements, in '94, is perhaps difficult to decide. It has given a vastly better course; but the difference between the lines *a b* and *c d* shows that the College has lost the opportunity to benefit many hundreds of students who have, as it is, been compelled, in most cases, probably, to go into business without professional training and who are thus placed almost hopelessly in the rear of their more fortunate fellows in their struggle for success through life.

Replying to the inquiry of the board, regarding this matter, the writer has recently made the following statement:*

The steps which may be expected to lead to further increase in the requirements for admission and to make them the equivalent in non-professional studies, or more than the equivalent of the existing academic examinations are:

(1) The demand *on the part of the profession* for so advanced a course as will permit the further rejection of non-professional studies from the courses of Sibley College and their remission into the preparatory schools or the academic departments of the University.

(2) Preparation on the part of preparatory schools generally to teach, in their scientific departments, fully and satisfactorily, the needed non-professional subjects—mainly pure and applied science.

(3) The advancement of the principal and leading professional schools of engineering to the grade already attained by those of highest requirements.

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* Sibley College Report, 1898.

(4) Ability on the part of pupils coming forward from among the "Industrial Classes," generally, to give time and money to secure the requisite preparation and a four years' professional course of the standing proposed; deferring going into business the necessary length of time. This is now a rare case among "Industrial Classes."

(5) General approval by the profession of engineering of the proposed policy and courses.

(6) Such change of circumstances and of views of educational matters as shall lead the "Industrial Classes," generally, to view with favor compulsory action of schools of engineering demanding a general education of maximum high-school grade as a prerequisite to admission to professional schools whose work has no immediate or essential connection with the educational system.

(7) As an essential supplement, and properly as preliminary, to the establishment of artificial systems of professional study for which a liberal education shall be the demanded preparation, the organization of Schools of the Mechanic Arts both to meet the needs of the great majority of pupils coming from the "Industrial Classes" and to comply with the spirit of the contract with the United States Government and the States.

"The principles which should be held in view in building up a technical institution are simple and definite. They are substantially these:

"(1) In seeking to aid the people in this field, as in any other, it is essential that those proposing to conduct the business offer the people what they desire and need, not, as so often is the case among the older colleges, what the vendor prefers to deal in.

"So long as the colleges offered only classical and academic courses, however well taught, they met the requirements of but comparatively few citizens. When they commenced the construction of the schools and courses of applied sciences, and gave opportunity for the acquirement of technical learning, they began to meet the needs of the great mass of the people and response was prompt. Colleges had lost ground, relatively, for years previously; they have, in these later years, regained all they had lost, and have taken up a rapid, and rapidly accelerating progress.

The State universities have owed a phenomenal growth to the extension of their fields of work into those which are of immediate interest to the average citizen, who, however much he may desire to give his son a liberal education, is through force of circumstances unable to provide both education and professional schooling.

"On the other hand, it can not be questioned that this revival of college work has done much to promote the renewed growth of the classical and liberal courses. Every youth going into engineering or architecture has a dozen friends who would gladly accompany him, and, among them some who, unfitted for professional work of a technical sort, will find or make a way to secure a liberal literary or scientific education.

"(2) In doing business, in this as in all other departments, that institution will do the best business which best supplies itself with the special talent required to carry it on, and, no less important, with that equipment which permits its work to be easily and thoroughly well done. Each teacher must be a specialist and an 'expert' in his own field.

"The builder of steam-engines must not only supply to the market just that kind of machine which his customers seek, regardless of his personal preferences, but he must be prepared to show that he has a staff of experts to design and construct and to set in operation such apparatus, and also that he has an establishment and an equipment adopted to do the work promptly and well. Other things equal, that institution which is known to be best prepared to supply what is sought by would-be patrons and is possessed of the most complete organization of educational experts, and the best material equipment, thus insuring prompt and satisfactory performance of the promised work, will secure the largest patronage. In the present case, the first endeavor was to offer what the people most needed, then to collect the best possible body of specialists in sciences and arts most closely related to the work, and finally to give this staff an ample and well-chosen collection of the apparatus needed for their several purposes. Specialization and precise adaptation of each individual, and of every piece of apparatus, to a special purpose, constitute the main points.

"As numbers increase, this last requirement becomes easier of attainment. Where five hundred men are to be thus taught, fifty instructors should be provided, and each may, and should be more or less of a specialist, and every task should be assumed by some one peculiarly well prepared for the work. Where two or three hundred men are to be handled in a laboratory of applied mechanics, for example, many testing machines must be provided, and it is easy to secure great variety of style and size. Were numbers reduced to a dozen, as in many of our own colleges in this department, and as in most of the European laboratories, even where presided over by the most famous men in the profession, one man must teach a number of lines of work, and a few pieces of apparatus of limited range in character and capacity must suffice for all.

(3) Demand of candidates for matriculation the highest amount of preparation that can with any degree of reason and under the special conditions of the case be expected, keeping fully up to the standard of the best and always ahead of the average preparatory schools.

"Thus the colleges and the schools gain mutually, and all practicable progress is made in the improvement of both. Thus, too, the student entering the professional school is enabled to give his time more completely to his professional studies, and for every hour saved in elementary work to substitute an hour of professional work, or even what is for the time graduate work, in research.[*]

THE UNIVERSITY stands above all educational institutions academic or technical, scholastic and gymnastic or scientific and professional, and *a true University*, employing the word in broad etymological sense rather than as so often conventionalized, should offer "instruction in any study" and should include faculties of all the sciences, all the literatures and all the arts of the time. We do much for pure science, much more for literatures and tongues, next to nothing for the arts; and yet it is upon progress made in the arts that the whole material advancement of a people depends; and it is only upon a basis of material prosperity that the highest and best civilization, intellectually and morally, can be firmly and permanently constructed.

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[*] Am. Univ. *Magazine*, 18[illegible].—R. H. T.

Nothing can be done for university or other schools of the industrial arts until capital and an assured and ample income can be found by the state and by private liberality for the special work. Plato, and all his modern disciples among great men, have asserted that it is a chief duty of the State to provide and to promote education of the people for "the future of their lives," for the life and work of the people, inclusive of their reciprocal duty toward the State. Milton would have education provided, as would Comenius, such as would best fit the people to "perform justly, skilfully and magnanimously and the offices, both public and private, of peace and war," and he believed that, as he said, "architects, engineers, mariners and anatomists" would gladly aid in the foundation and organization of a school making, as it should, "enginery, architecture, fortification, navigation," and "natural philosophy," essential elements of its curriculum.

In the education of the people for the life and work of the people, nothing can ever do more for them than can schools of the industrial arts.

DISCUSSION.

President Johnson said that probably the chief points in the paper calling for discussion might be found in (1) the question of prospective elimination from professional engineering schools of what is commonly known as undergraduate work, and the relieving of these professional schools from the anomalous position in which they now find themselves, as being both undergraduate schools and professional schools in one. He anticipated the time when these would be separated very distinctly; this subject is a very important one, not as calling for immediate action, but as one on which action might well be held in anticipation. (2) All those engaged in teaching in the State of New York would like some expression as to the advisability of allowing entrance requirements, as well as the scope and amount of work done in the engineering schools, to be controlled by an organization like that of the Regents of the University of the State of New York.

Professor C. M. Woodward said that he would try to limit his remarks to the questions that had just been outlined, but that there were many other matters suggested in the paper about which he would like to talk if there were time in which to do so. With reference to the suggestion that high schools should be technical, the speaker said he objected to the word "technical." He thought that no subjects taught in the preparatory schools should be termed technical; that this word should be used only as referring to the training in the higher, the professional institutions. Mathematics, history, languages, etc., should be called simply education, and not technical education. It is misleading to call any high school or secondary school technical. People get the idea that they are not for general usefulness, according to the demands of the time, but that they are for the making of mechanics of a low grade. The speaker further said that he did not approve of Dr. Thurston's suggestion of making our schools more specially professional, like the schools of law and medicine, eliminating all so-called undergraduate work,—which, after all, is the backbone of the whole course. He emphasized his belief that pure mathematics and mechanics form the backbone of the whole matter and that they are as liberal and academic as any study could possibly be. He said that he was opposed to emphasizing the difference betweeen high-grade technical training and academic training; that he believed in liberal training along academic and scientific lines and that that should always constitute the main work of any high-grade school. He was opposed to such extreme differentiation as seems to be going on now. He had been training engineers for the past thirty years and had seen them in the midst of successful careers, as engineers and as business men, and he knew what they think and how they talk about these matters. The things that they value most, the things that abide with them and make them strong, are not the special, differentiated work along some line of applied science or applied engineering, but they are those things that underlie all their training in technical courses and are the backbone of the whole. The speaker thought that they make a great mistake who differentiate so early in engineering courses, starting boys off on this or that side-track. They are concerned about the boughs, twigs and blossoms, rather than with the trunk of the tree. If one has a solid, high-grade, scientific training, these applications along special lines will take care of themselves. The speaker knew of many engineers who, graduating in one course, have found success in another; and this ought always to be possible and logical. The bane of our education to-day is that men are not sufficiently versatile. They can not succeed in many things; they have not the special mathematics, or something of that sort, that goes with a particular thing; they are handicapped; they are not the broad men that the professional school of to-day should turn out. The engineering school of the future should be a liberal engineering school, and we should never eliminate general culture studies from an engineering course. The speaker said he believed that every student should have one study throughout his course of four years which should not be professional; that was the result of his observation and was his profound conviction. Let these differences appear in the laboratory, in the appliances to illustrate the principles that you have laid down, and that will emphasize them sufficiently. Laboratories may be suited to the conditions of neighborhood and environment, but it is a mistake to consult environment, in this connection too much. The speaker said he did not believe in the idea that the lower grade schools should teach trades according to the community in which they are placed. He believed that the school should lead the community, and not be led by it. As to how far should we yield to the traditions and prejudices of academical people, he should answer, not at all; let us stand on our own ground and maintain our dignity; let us yield no point of the dignity of high-grade technical training. As to the Board of Regents of the University of the State of New York, the speaker thought it should be legislated out of existence if it was one-sided in its views and methods.

Mr. Kent said he thought that it would be well to get some idea of the ends that the engineering schools of the country have in view; that there seemed to be a difference of opinion as to what an engineering school is for. In the speaker's opinion, if the end is to turn out a small, highly distinguished body of men with a degree attached to their names, who shall be privileged and advanced above the ordinary man, just as the man with the degree of M. D. is privileged,—and he can not do his work without the degree,—it would be well to progress along the lines suggested by the paper; and he thought that is one tendency the schools are developing. The other idea of the engineering school is that the State wishes to educate a large body of its citizens in such a manner as to make them of the greatest good to the community at large. That is the idea on which many of the engineering departments in the State Universities are planned, the end in view being, not to select a small number of men and decorate them with a degree that no one else has, but to take a larger number and give them that kind of engineering education which will advance them as far as their abilities will allow them to go; granting them not necessarily a degree, but certificates showing what they are able to do. . He thought we must consider these two styles of engineering education,—one adapted to the needs of the community at large and the other to the education of a small number of men for distinction in the profession. It would be a mistake to attempt to lay down grooves for engineering schools to run in. They must depend upon the kind of education demanded by the sentiment of the community, and we can not be confined to one particular style of school. The speaker said that it may be that Cornell will necessarily advance its requirements so that one day the engineering departments will have no undergraduate work whatever; and the Massachusetts Institute of Technology, also, may follow this line; but this ought not to be the case for fifty years yet for the western and southern schools. They must take men out of their communities and give them the kind of training they are able to receive.

Professor Fletcher heartily indorsed Professor Woodward's remarks, saying that he had for more than twenty years had the honor of presiding over an institution which was founded in 1871 on the lines suggested by Professor Thurston's paper, as a purely professional school, relegating to other institutions the purely preparatory work, thus confining the courses to the strictly professional work; and the speaker was ready to say, without making any personal allusions, that in so far as that school has had success, it has in his opinion been because of the high standard set for the requirements at entrance. This plan of the scope of the school was made a distinctive feature from the beginning, and the exclusion of any preparatory courses was necessary by reason of the small endowment; but at the time the school was started it was nearly impossible for any young man to meet the requirements unless he had had a college course. This experience has shown that such men are usually the best all around men; they can best adapt themselves to the exigencies of actual practice. Some students had been enabled to make "short cuts," because there was no specific language requirement; but almost all of the men had had some knowledge of Latin, French, or German; and in many cases where men had made short cuts they had afterward expressed regret that they had done so. In further sustaining Professor Woodward's argument, the speaker said that these men generally had found themselves able to specialize; and that some who had preferred one particular line at school as being that which they expected to follow ultimately, they had usually in the end gone into some very different kind of work. The speaker offered the above remarks to put in evidence one example of an institution maintained according to the principle, suggested in the paper under discussion, of a distinctively *professional grade* for an engineering school.

8. Professor Ayres thought that the conditions which would allow of the maintenance of purely engineering schools in this country exist only, as Mr. Kent had just said, in a small part of the country, and that it would probably be many years, if ever, before the country would be in a condition to support any large number of purely professional engineering schools. It seemed to the speaker, therefore, that for the present the way out of the difficulty is to be found in so planning the courses of instruction that the culture courses shall be largely disciplinary and educational in the broad sense, with only a moderate direction toward engineering, and in graduating the student in such a course with the B. S. degree; then the few men that have time, ability, and inclination, may pursue graduate courses leading to professional degrees. This is very largely the practice abroad, but is not general in this country, where the degree of M. D., for instance, is given at the end of a three years' undergraduate course. It seemed to the speaker that the difficulty might be met in a single institution, by not differentiating sharply between different lines of engineering and culture studies, but making the differentiation take place

in the graduate work leading to the professional degree. An extreme differentiation of studies in the culture course has all the objectionable features that had been pointed out by Professor Woodward; but after the student has a general basis for his training he is prepared to differentiate and specialize as much as may be necessary to warrant giving him a degree. In reference to Professor Woodward's argument that engineering schools should not be led too much by environment, the speaker said he concurred with that in the main, but thought it would be a mistake if engineering schools did not to some extent consider natural conditions of location and develop along those lines. It would be unwise for a school in Colorado to decline to specialize somewhat in the direction of mining, or for a school in the South to refuse to pay any attention to the manufacture of cotton; in such cases, the conditions are put upon the school by its location, and no pressure brought to bear by the school could possibly change those conditions. There should be no attempt to form any specific plan which should be applicable to all the schools of the country without respect to location.

REPORT OF THE SECOND COMMITTEE ON UNIFORMITY OF SYMBOLS.

At the Springfield meeting of the Society, held in 1895, a special Committee on Uniformity of Symbols was appointed, a report of progress was made in 1896, and a tolerably complete report was made to the Society at its meeting in 1897.

As this has already been in the hands of the members of the Society for over a year, no detailed reference to it is necessary at this time. Considerable discussion took place when it was submitted to the Society, revealing a great variety of views in regard to the fundamental principles involved. For some reason unknown to the members of the Committee making the present report, and thus far undiscoverable by them, the Society saw fit to discharge, honorably or otherwise, the Committee then reporting, and to appoint a new one. Some of the members of the new Committee were not consulted as to their desire or willingness to serve, and not until some time after the adjournment of the meeting of 1897 were they notified of the task which had been thrust upon them.

In obedience, however, to the instructions of the Society, the Committee has considered the question in the light of said report and discussion and begs leave to submit the following remarks and recommendations:

The Committee of a year ago agreed, in advance of the preparation of its report, upon a few "Guiding Principles,"—four in number. The discussion brought out the fact that even these were by no means unanimously approved, and perhaps not more than two would be accepted by the present Committee. Separate and very complete reports were made by individual members of the Committee; by Professor Jackson on Electrical Engineering Symbols; Mr. Wm. Kent on Mechanical Engineering Symbols; Professor Galbraith on Symbols used in Mechanics, Hydraulics, and Thermodynamics; and by Professor Johnson on Symbols used mostly in Civil Engineering and Surveying. These, together with the four "guiding principles," constituted the report proper, but its value and interest were greatly enhanced by critical remarks of several members of the Committee.

The carefully prepared report by Professor Jackson on Electrical Engineering Symbols is, undoubtedly, well known to all interested in this department of engineering work. It might have been assumed in the beginning that here the task would be less difficult than elsewhere. Electrical engineering is fortunate above all other examples of applied science in that it was a science before it became an art. It owes its wonderfully rapid development to that fact and especially to its beautifully simple scheme of units of measure by which its already numerous and continually multiplying magnitudes are so easily and accurately related to one another. In its metrology and nomenclature it can not but excite the admiration and envy of all who are compelled to submit to the illogical and clumsy systems that prevail in other branches of engineering. Among electricians there can be little debate as to the meaning of fundamental terms; they have long ago come to an international agreement concerning these, and their definitions have been officially determined. Professor Jackson has referred to the report of the Committee of the Chamber of Delegates at the International Congress of 1893, in which a large extension of this agreement to the nomenclature and notation of derived units was proposed. He has also stated the conservative action of the Chamber in declining to vote either for or against this report. Indeed, this illustrates the extreme difficulty of adopting an extensive system of notation, even when there is apparently little difference of opinion. Although the report of this committee has received the endorsement of the Units Committee of the American Institute of Electrical Engineers, Professor Jackson does not recommend it to this Society, but, instead, offers a scheme of his own which is, in many respects, admirable. Under the circumstances, and at the present time, however, it seems unwise for this body to commit itself to any system not in harmony with the report of the international committee at Chicago, especially as this is indorsed by the largest and most representative body of electrical engineers in this country. This does not mean that the system recommended by Professor Jackson is not superior to that of the Chicago Committee, but rather that the process of evolution has not proceeded far enough to justify the affirmative action of this Society.

The difficulties in the way of the development of a complete nomenclature and notation in electricity are trivial and relate mostly to matters of detail, but in the opinion of your Committee it is wise to move slowly; to confirm rather than determine. It believes that the great danger to be guarded against is the unnecessary and uncalled for naming of units and the creation of confusion and obscurity by the useless multiplication of symbols.

This danger seems imminent in the very elaborate and carefully prepared schedule in mechanical and civil engineering, of the committe of last year. Mr. Kent recommends the adoption of more than two hundred symbols in mechanical engineering, and there seems to be no reason why he might not as well have extended his list to five hundred or more. He necessarily uses the same letter many times,—in one case, at least, not less than twenty times,—and to stand for magnitudes entirely unrelated to each other. It is difficult to see what would be gained by voting to approve such a list as this. There may be some reason in agreeing to use a certain symbol or certain symbols to represent angles, but why require an entirely different symbol, and one used for many other unrelated magnitudes, when the angle is made by a bend in a pipe? Symbols are provided for known distances and for variable distances, but nothing for *unknown* distances. These remarks are not made in criticism of Mr. Kent's scheme so much as to invite attention to the fact that when once a system of abbreviated notation is pushed beyond a certain point it necessarily breaks up of its own weight. It is doubtful if any *generally* accepted set of abbreviations should go beyond what is easily carried in the memory of the average reader, who must always depend largely upon the context for the meaning of words and symbols. To go beyond this would simply compel consultation of an index or table, and when this is necessary it makes little difference what symbol is used. Often one will be much more suggestive than another and in one place one will suggest what another will not; and for this reason a large freedom ought to remain with the writer. While in ninety-nine cases out of a hundred one will naturally use r to represent the radius of a circle, in the hundredth case another letter or symbol will be vastly more appropriate and effective.

While these remarks apply in some measure to the system recommended by Professor Johnson for civil engineering and surveying, there is much in it to be strongly commended. Evidently prepared with much care, it is consistent and is meant to be suggestive as to related quantities. The principal objection to it is the large number of terms included. In this respect, as well as in many others, your committee heartily approve the report of Professor Galbraith. Restricting himself to forty magnitudes, he has selected from the whole domain of physics and mechanics only those of the greatest relative importance or of the most frequent use. To these he has attached symbols that general usage has long ago assigned to them, and his system thus represents an evolution rather than a creation. It is not certain that still further reduction in number might not be advantageous and a few modifications may well be suggested before the Society should affix the stamp of its approval.

The reports of the members of the former committee, as well as the very interesting discussion which followed their presentation, made very evident the fact that there were differences of opinion among members of the Society more serious than could arise out of a simple question of symbols. There is a very decided lack of agreement as to the meaning of several of the most fundamental terms in mechanics, as well as to the form and meaning of some of the fundamental equations of mechanical science. In respect to these it has been intimated that there is naturally and must continue to be a wide difference between the so-called scientific treatment of a problem and its so-called "practical" treatment; that the terms, definitions, equations, and symbols that are best for the one are not best for the other. Your committee believes that such an assumption is at once unscientific and unpractical; that Engineering, in all of its departments, has risen to the dignity which it now enjoys and to the success of which it now boasts, by, and only by, the aid of pure science, and that the more nearly it becomes rigorously scientific, especially in its great underlying principles, the more perfect will it be.

It is of the utmost importance that these differences as to fundamentals be removed. The adoption of any system of Engineering nomenclature or symbols is practically impossible while they exist.

Your Committee, therefore, recommends:—

First,—That no action be taken by the Society at this time in reference to Uniformity of Symbols;

Second,—That the whole subject be referred to a new committee, with instructions to report definitions of the fundamental quantities used in engineering, together with such recommendations as to their symbolic representation and the fundamental equations relating them to each other as they may deem desirable.

Respectfully submitted,

T. C. MENDENHALL, Chairman.

[The Committee making the above report consisted of Professors T. C. Mendenhall, Storm Bull, H. S. Hering, G. F. Swain, and R. S. Woodward. The correspondence submitted with the report shows that the Committee was practically unanimous on the report as a whole; one member dissented from the second of the recommendations.—EDITORS].

DISCUSSION:

PROFESSOR MERRIMAN said that, in order to bring the subject before the meeting, he would move that the first of the recommendations of the Committee be adopted, as the action of the Society.

It was accordingly voted that no action be taken by the Society at this time on this subject.

It was moved and seconded that the Committee be continued.

Mr. Kent opposed this motion, saying that, in his opinion, the Committee should not be asked to do what it did not want to do; and he substituted a motion to lay the report of the Committee on the table.

Dr. Mendenhall rose to explain that the Committee did not recommend the further consideration of the question of symbols for engineering; but that in the judgment of those members of the Committee who approved of that particular paragraph it is desirable to proceed first with the definition of the fundamental terms and equations, and that was what the Committee recommended for consideration by a new Committee.

Mr. Kent objected to this recommendation, saying the time for such action had not yet arrived, and that if any member of the Society thought the matter is not clear enough, he should write a paper upon it and present it for discussion. The speaker said the time is not yet ripe for a committee of this Society to prescribe to engineers the terms they should use.

Professor Gray said that it seemed to him little good could be obtained by continuing the Committee. It appeared to him that the subject of Uniformity of Symbols was not ripe for consideration by any Society whatever. He was opposed to uniformity and thought that if there were a book of symbols it would greatly hamper the writing of engineering books. The speaker said he would not undertake to write a book which should conform to it, and that if one were forced to refer continually to some hard and fast line of writing so much intellectual energy would be consumed in that way that it would be difficult to accomplish anything. He thought the existing conditions were better, and that every one should use the symbols most convenient to him. If those symbols be properly described no one need have any difficulty in reading the book.

Professor Allen said that inasmuch as the action of the Society indicated that the Society did not wish to take direct action upon the question of the continuance of the Committee, he would move that this question be left to the incoming Council with power to act. As he remembered it, this matter had been in the hands of the former Council; and he thought there would therefore be no impropriety in referring it as proposed.

On motion by Professor Swain it was voted that Professor Allen's motion be amended to the effect that the Report of the Committee on Symbols be accepted and the Committee discharged.

The motion as amended was then adopted.

ELECTRICITY IN ENGINEERING COURSES OTHER THAN ELECTRICAL.

BY J. P. JACKSON.

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The present extended use of electricity in industrial undertakings has made a knowledge of its control indispensable to the well rounded engineer. It is true that the members of the mechanical, mining, and allied engineering professions may need a wider technical training in this subject than architectural, civil, and sanitary engineers, or others doing similar work; but even if this is so, the distinction is not great enough to make it desirable to give a different training in electricity to undergraduate students in these various courses.

College courses preparing for the older engineering professions were established while engineering from a scientific standpoint was still in its infancy. Through human inertia these courses have tended to continue on their old lines. The present time therefore finds training in electricty far from satisfactory in engineering courses other than electrical; that is, when the collegiate education of the country as a whole is taken into consideration. If the colleges and universities are considered individually, a few will be found in which all the engineering courses give a thorough training in electricity, others in which some of the courses include such a training, and others in which this work is omitted entirely. Civil engineering and its branches, having been established in many of our colleges before there was a call from the industrial world for either mechanical or electrical engineers, will be found, in many institutions, not only to have excluded electricity from the curricula, but also to have slighted steam, general design, etc. The resulting courses, considering the present advanced state of the applied sciences, are extremely narrow or specialized, and, in the writer's opinion, better adapted for graduate work. Mining engineering is rather more generous in the allotment of time for electricity, in those institutions which have made a specialty of mining; but in many instances such courses have sprung from the narrowest civil engineering courses by the addition of more or less metallurgy. There is less criticism to be made of mechanical engineering. In many institutions the extent and quality of the electrical work as found in the mechanical engineering courses are satisfactory, but there are numbers of institutions in which such courses need reorganizing in this element of their curricula.

The following table indicates more specifically the actual existing conditions. The data for the tabulation are drawn from the schedules of forty representative colleges and universities, which have, after deducting the electrical, ninety-three engineering courses. One recitation or two hours of practicum are counted as a period.

NAME.	Total number of courses.	Periods assigned to Electrical Engineering.				Per cent teaching more than 55 periods.
		0	1 to 55	56 to 100	More than 100	
Mechanical	26	5	7	7	7	54
Civil.........	34	20	5	7	2	26
Mining	16	7	3	5	1	37
Architectural.........	7	6	.....	1	.. ..	14
Sanitary.............	7	6	.....	1	.. ...	14
General Eng...... ...	3	1	......	.....	2	67
Totals.	93	45	15	21	12	34

All undergraduates study the electricity and magnetism of the general college course in physics. Some are given a term in addition to this on the applications. Few receive a rigorous advanced treatment of the subject from the engineering standpoint. The college physics course might as well be depended upon to give the requisite training in applied mechanics or thermodynamics. To the work now usually scheduled, a thorough drill in the laws of direct and alternating currents as they apply to the practical utilization of electricity should be added. This should be taught by an engineer, and should be assigned time comparable with that given the steam engine, hydraulics and hydraulic machinery, etc. The time could be obtained with advantage by cutting off or compressing the more special lines of work. For instance, the beautifully inked bridge designs with accompanying minute details, and similar work, which are viewed with such awe by the college visitor, might be reduced to plain working drawings; or the long mathematical treatments sometimes used in the development of engineering formulas might be replaced by shorter and clearer paths to the result; or again, work of a descriptive nature which is intended to give merely technical information, such as will be obtained later in the field, can always be replaced with advantage by subjects dealing with the fundamental principles of an engineering science.

In studying the question more in detail it is desirable to consider first the training in physics. Electricity and magnetism are usually assigned a fair share of the total time given to physics. Unfortunately, however, the time is not always utilized to the best advantage for the engineer. In one of the catalogues examined before writing this paper, a professor of electrical engineering remarks that the first thing he does with new classes is to give them a course on the elementary principles of electricity and magnetism, such as they will need in their advanced work. In the case under consideration this took a full term and must have been required largely because the course in physics lacked in essential elements as a preparatory training. Instructors in mechanical engineering meet the same difficulty when teaching the steam engine, etc., from the character of the preparation in heat. A similar case, though not exactly parallel, would be one in which the engineering instructor was compelled to review certain portions of the mathematics before proceeding with his legitimate work. Such a state of affairs would not be tolerated; the engineer says to the mathematician, "You must prepare your students to take my work." An equally strong stand should be taken in the case of physics. The course, to meet such a demand, should consist of a clear presentation of the fundamental laws of the electric current, magnetism, electromagnetism, electrostatics, and electrochemical action. The laws treated fully should be those bearing directly upon the utilization of electricity. Other matter should be merely touched upon for the purpose of giving information, without spending much time upon its development. As a rough estimate of the division of time to be given under these several headings, I would suggest about three-fourths to the electric current and electromagnetism, and the other fourth to those remaining. Instead of the ordinary treatment of this subject, the engineer would have the work on electrostatics much curtailed; charges on peculiar shaped surfaces, images, etc. are not of great service to him; he would reduce the chapters on thermoelectric currents, the earth's magnetism, and other material of a similar nature; and would probably not care to have his students, while in the sophomore class, particularly interested in the "curl of magnetic field," as such. In fine, he would have the teacher of physics adhere strictly to the basic laws, developing from them useful working formula and aiding the student's conception by the use of aptly prepared problems. The argument may be made that the course would thus be narrowed and weakened; this I wish to combat in advance. The student taking such a course could be made to appreciate the true physical significance of the subject; the important facts would not be inextricably mixed with the matters of small concern to an engineer. The accompanying laboratory work should aim at the same result as the class room work, in addition to giving the student a thorough drill in accurate *quantitative* measurement.

Having received such a preliminary training, the student enters the lecture room of the instructor in electrical engineering prepared to take up technical work at once. This will naturally begin with direct currents. The laws already considered will now be developed more fully, with special reference to their application to useful machinery. The next section of the subject, alternating currents and alternating current machinery, will be taught with direct reference to the alternator, transformer, polyphase apparatus, etc. Finally, the fundamental principles underlying the distribution and transmission of electric power will be presented. Along with this course a certain amount of information will naturally be given concerning the details of individual machines and commercial processes, but rather for the purpose of illustrating principles than for its technical value. The work should be made stiff and rigorous and should be carefully shorn of all that is unnecessary. "Little time can be spared for historical work or classical experiment, except where such material is of value as an aid to the general result;" neither can time be spared for the description of special makes of machinery or apparatus. Moreover it should be "sought to avoid either the error of presenting unnecessary formulas, or, on the other hand of giving results without reasons, both of which are fatal to the student's true progress, as they leave him with no true physical conception of the phenomena studied."* Or, to look at the question from a different point of view, the subject should be taught very much as is mechanics of machinery; that is, by the development of formulas as they apply to the various general classes of machinery and apparatus. Having had such a course, the engineering graduate should be readily able to apply his general knowledge to the specific problems which he may be called upon to solve. If the work is taught by a competent engineer, it seems scarcely necessary to say that it must be done with reference to actual physical conditions and not on theoretical assumptions. Yet the failure to fulfill this last condition has been the cause of much weak college training in electrical engineering. The laboratory practice should be arranged to clinch the principles presented in the class room, but at the same time it can and should be made to give a thorough training in practical testing and in the proper handling of electrical appliances.

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* D. C. and J. P. Jackson. *Alternating Currents and Alternating Current Machinery.* (Preface)

For this work the writer believes in text books or in their equivalent, mimeographed lecture notes, as the text, accompanied by proper library references, gives the student a satisfactory opportunity for individual study, and likewise permits the instructor to use much time in the class room for explanations which would otherwise be taken up in delivering lectures for the student's note book. But the selection of a text book is difficult, and after it has been selected great care must be exercised in eliminating useless material. In fact, in a large majority of the text books on both elementary and technical electricity, from one-third to one-half of the matter might be cut out. The time saved could with great advantage be used in an extended drill upon the part taken. From personal conversation I know that many engineers agree with me in this view and have no doubt that it is generally accepted.

The time given to the advanced course in electricity should not be less than seventy hours in the class room and sixty actual hours in the laboratory. This question of time is of course one of the most serious problems to be met, as it means cutting other work; but if at all satisfactory results are to be obtained, time approximating that suggested must be given. As a rule a conscientious professor of electrical engineering would much prefer not to teach at all than to have his work so abbreviated as to become merely a superficial description of machinery and processes, of little value to the student and soon to be forgotten.

As scientific knowledge increases, undergraduate engineering courses must give more and more attention to fundamental laws and principles at the expense of mere technical practice. The question of giving time for electricity in the old established courses of engineering is merely one step in this general process of evolution. Moreover, electrical engineering courses, the latest engineering courses on the field, are in many colleges taking an exceedingly strong position when compared with their fellows, as indicated by the stand of those in charge when they assert in the college catalogues that the electrical graduates must be mechanical engineers and have the essentials of civil engineering. One well known professor of electrical engineering states positively that he expects his men when graduated to be fairly well trained in the fundamental physical laws of all engineering and that he can afford little time for details of practice, even in electricity. This condition tends to make engineering courses, leading to whatever degree, converge. It might even be prophesied with some hope of fulfillment that in the future technical colleges will give one engineering course, with possibly a few electives, and that the differentiation will be reserved for post-graduate work.

In closing, I should like to say that if electrical engineering studies are to be taught satisfactorily they must be under the supervision of an engineering department, and should not be taught by instructors in the department of physics. The professor of physics has taken a college course in pure physics, has taken several years of post-graduate work in pure physics, and is engrossed in the development of pure science without reference to its applications. The engineer has probably had an equally good training for his work in the college and the industrial world, but his object is constantly the application of science to the welfare of man. The points of view of the two are quite different. Each has his own work to do and they should not be thought to be interchangeable.

DISCUSSION.

Professor Hibbard said that it might interest the members of the Society to be told of one course in which electrical engineering is given a prominent place. At the University of Minnesota (and hereafter at Cornell) the student who elects the special senior year in railway mechanical engineering is required to take as much work in electric railway subjects as is required of those who are to be electrical engineers. The speaker said that, being a steam railway mechanical engineer, he could speak with freedom of his profession; and he thought that it was to their shame that the steam railway companies have quite generally thus far permitted suburban traffic to be diverted to the purely electric companies. He cited the instance of Minneapolis and St. Paul, with centers ten miles apart and connected by seven trunk lines of steam railways, where the interurban passengers are almost wholly carried on an electric railway, which has cars as large and commodious as steam railway cars, and which does a crowded business at great profit, notwithstanding the fact that it takes the electric car in the street forty minutes to make a trip between the two cities which could be accomplished on the protected steam tracks in very much less time. The speaker expected to see a change in these conditions, and thought that one thing that will bring it about will be the preparation of the young railway mechanical engineers by courses calculated to fit them to promote and look after short-distance electric railway service in connection with and under the control of the wealthy steam railways.

PROFESSOR RANDOLPH called attention to the difficulty of operating electric cars and steam cars on the same tracks. He expressed his pleasure at hearing the paper, as it brought out facts in connection with a subject on which he had been working for a year or two. He said there are six or seven different methods of transmitting power, and the mechanical engineer that is not prepared to solve the problem by the use of electricity is out of his sphere. The same is true of the electrical engineer that has only the training in electrical engineering and not the mechanical training necessary to solve the problem. The speaker's idea was to have a mechanical engineering course so arranged that the students would understand electricity as well as they understand steam engineering.

PROFESSOR CALDWELL agreed in almost all particulars with what had been outlined in the paper. The speaker said that it appeared to him that mechanical engineering and electrical engineering courses must converge in the near future. That is, the mechanical engineer that has not a thorough training in electrical engineering and the electrical engineer that is not trained in mechanical engineering are both anomalous; and future changes in the two courses should be in the direction of bringing them nearer together.

The speaker said that in the Ohio State University electricity had been introduced in all of the engineering courses to the extent of about one hundred periods, but that is really not enough; it is only enough to give the barest general outline of the work; and, in the speaker's opinion, the time should be considerably extended in the courses in mechanical engineering and mining engineering. It did not seem to him quite so important in the case of the civil engineer as in some of the other courses.

Professor Bull expressed himself as feeling very strongly that the electrical engineer ought to be first of all a mechanical engineer. Mechanical engineering is the fundamental course; whatever else may be added to it will be useful, but mechanical engineering is the backbone. He was afraid that the differentiation has of late been carried so far at some places that the electrical engineering students get very little mechanical engineering.

Professor Adams was of the opinion that if Professor Bull would look at the facts in most colleges he would find that the electrical engineering students get a very good share of mechanical engineering. The speaker felt strongly that Professor Jackson's emphasis of the importance of more electrical instruction in the mechanical and civil engineering courses is a very timely one; for, in the speaker's judgment, the mechanical and civil engineering students in many of our engineering schools do not receive an adequate training in even the fundamental principles of electricity; whereas the electrical engineering students frequently receive as much instruction in the practical details of boilers, engines, etc., as in the practical details of electrical machinery.

The speaker said that at the Lawrence Scientific School the amount of electricity given in the non-electrical courses had just been increased; and there is now a course which includes two hours of lecture, one of recitation, and six hours of laboratory work per week for a whole year. In this work, which is additional to the electricity given in the elementary physics courses taken by all engineering students, it is possible to give the students a fair foundation, not only in the principles of the flow of direct currents, and their applications, but also in the elementary theory of alternating currents. The speaker was much pleased to note the results of this extra instruction especially in the alternating current work, and to find that the men that were counted upon to do good work in the class acquired a good working foundation in the subject.

Professor Marburg said that he heartily indorsed the views expressed in the paper, in so far as they related to students in mechanical engineering. Referring, however, to students in civil engineering, he would dissent somewhat from the conclusions of the author.

He thought it necessary in this connection to recognize clearly the distinction between what is desirable and what is practicable. It is doubtless desirable that the civil engineer should have a good knowledge of electrical, and no less of mechanical engineering; but, with entrance requirements as they now are, he did not think it practicable to accomplish much in these directions in the usual four-year course. He thought that the professors of electrical engineering should themselves be opposed to an attempt to cover the ground in too short a time. While he would be only too glad to have his students obtain a good knowledge of electricity in its practical applications, he had come to the conclusion that, under the circumstances, its attainment was impracticable; that the study of electrical engineering could not be emphasized to such an extent in a course in civil engineering, without detriment to other subjects of more direct importance to the civil engineer.

The speaker thought it important, under these conditions, not to attempt to give a thorough course in applied electricity, but to make sure that the theoretic side of the subject was well presented. He thought that this theoretic treatment might be supplemented to advantage by a brief descriptive course covering the most important features in the design and use of electrical apparatus, but this course must be confessedly superficial; the student must understand that it is impossible to treat this subject thoroughly under the unavoidable time limitations, but that it is desirable that he should have at least such general knowledge of the subject as can be acquired in such a course.

Professor Jackson said that he had understood Professor Marburg to intimate that his paper referred to teaching the small details and variation of manufacture as practiced by different makers: that is, to the mere practice of building and inspection of special machines, and other work of that nature. The speaker wished to state positively that he did not mean that. He wished to say that he believed in teaching and studying the theory of direct and alternating currents with direct reference to their application, and not in wasting time in describing the details unessential to the development of the theory. He thought it wise to strongly emphasize the desirability of keeping very carefully away from all matter of a descriptive nature that is not of use to the student in understanding the principles that he is trying to grasp; and such a course, designed to develop the useful laws of electricity, would, he believed, be of service in any department of engineering.

A COURSE IN INDUSTRIAL CHEMISTRY FOR TECHNICAL SCHOOLS.

BY FREDERICK L. DUNLAP,
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Industrial chemistry is simply the application of chemistry in the manufacturing and production of articles which have commercial value. It may be applied to such manufacturing processes as the production of sulphuric acid, or to the production of prints in the bleach and dye-works, in both of which processes the principles of chemistry play the all-important rôle. On the other hand, the part that chemistry plays may be entirely subsidiary to the process, as in the case where endeavors are made to produce substances of commercial value from waste products or by-products. It is thus seen that industrial chemistry, while being scientific, is purely of a professional nature. The problems to be investigated, while being problems in pure science, have other ends in view than the mere solution of the problems. The main object of the solution of an industrial problem is to make it apply to some useful end. Industrial chemistry is fundamentally utilitarian.

The teaching of industrial chemistry dates back into the last century. Göttingen has the honor of being the first institution to introduce a course in this work, and here it was that the first book on chemical technology was written. [J. Beckmann; "Anleitung zur Technologie," Göttingen, 1777.] Since the introduction of this subject at Göttingen, it has been taken up by nearly all of the great German universities, where courses are offered under the various names of "Chemical Technology," "Technical Chemistry," and "Chemical Industries."

This subject of industrial chemistry is, however, much more fully developed in the Polytechnicum and Technical High School, of which Germany has quite a number which are thoroughly equipped and which are doing most excellent work.

The Massachusetts Institute of Technology was the first institution in this country to introduce lectures on this subject, and it was Prof. F. H. Storer who, in 1865, took the initiative in this line of work. It was at this same institution that Prof. John M. Ordway, in 1874, opened the first laboratory for industrial work. Courses in industrial chemistry are now offered at the Worcester Polytechnic Institute, at the University of Michigan, and at Columbia University.

Certainly no country has greater industrial possibilities than ours; yet we have many valuable lessons to learn from Germany, whose sons have not only made their Fatherland famous for their achievements in pure science, but who have also, by their practical application of pure science to some useful end, raised Germany, in but a few years, from the condition of a country chiefly agricultural, to one of the most powerful industrial communities in the world. The enormous industrial development of Germany is not to be attributed to science alone, for there are other reasons for her development which may be easily traced; yet it is not to be disputed that her scientific achievement has played a more important rôle than any other cause that may be assigned. Consider but for a moment that the number of persons employed in Germany in chemical industries has increased seventy-two per cent since the Franco-Prussian war. In engineering industries the increase has been fifty-seven per cent, while the agricultural population has decreased since 1882 from forty-two per cent to thirty-six per cent. To-day, Germany alone has four thousand technical chemists, while the number of those interested in chemistry as a pure science does not exceed two hundred. The number of her technical chemists has increased three fold during the last quarter of a century. Her chemical factories employ forty-five thousand men, twenty thousand of whom are connected with industries making organic preparations and dye-stuffs, in which line Germany stands preëminent, while ten thousand five hundred are employed in her acid and alkali plants.

The more one studies the industrial development of Germany, the more one becomes convinced that the determining character of her success has not been due to specially favorable conditions, but to her method of scientific training. Her army of chemists labor unceasingly for the continual improvement of her processes, in the search for new ideas, and in the perfecting alike of details and of the industry as a whole.

Industry is the scene of the triumph of science. The German industries afford a most complete demonstration of the truth of this statement. They will ever prosper as long as the universities and technical schools turn out their hundreds of well-trained chemists, some of whom enter special branches of chemical work, while others follow a purely scientific career, but still keeping in touch with those whose knowledge is serving some practical end. There is a close collaboration between science and industry, and the results have been most brilliant. The appliances of the works are always at the service of the savant for experimental purposes, and, on the other hand, the man of pure science always examines willingly any problem that may be submitted to him.

A vast number of the German factories employ their own chemists. A single establishment alone, at Ludwigshafen (the Badische Anilin and Soda Fabrik) employs over one hundred highly trained chemists—more than are employed in the whole of England in this line of industry.

What conclusions are we to draw from all this? Simply that the Germans have learned the importance of the collaboration of pure science and industry—a lesson, I fear, that many of our own manufacturers have yet to learn. In order to establish this harmony between the factory and the school, the school must be able to turn out men equipped to grapple with those problems which are arising continually in practice. The processes involved in manufactures can by no means be looked upon as perfect. Many of them may be simplified and improved, and we may naturally look for many changes in methods. Our hope for industrial development will depend largely upon the ability of the men our technical institutions and universities turn out to master difficulties as they arise, to carry processes along to perfection, and to suggest new processes when conditions demand them.

I wish now to call your attention for a few minutes to a short discussion of a "Course in Industrial Chemistry for Technical Schools," for it is in the technical institutions, I believe, that this work belongs, rather than in the University proper, on account of its strictly professional nature. Of what does the chemical work presented by our technical institutions consist to-day? Inorganic chemistry, qualitative and quantitative analysis and organic chemistry, these courses having attendant laboratory work. These subjects are the main stays of the course in chemistry in our technical schools. Besides this, the student may be given instruction in chemical philosophy, advanced inorganic chemistry, journal reading, sanitary chemistry, gas and fuel analysis, and perchance some study of the history of chemistry, his whole course usually ending with a short thesis embodying some original work. What is the result of this study as seen in the student as he graduates and is ready to take up some pursuit in life? He has had, unquestionably, most excellent opportunities for laying a fine foundation for future chemical work. He is able to do intelligently all sorts of technical analyses, but he has no adequate knowledge of the practical application of his subject to the industries of his country. I think I am not wrong when I say that the principal stronghold of the student when he graduates is his capability to do technical analyses.

Is his knowledge of such a nature that he is able to cope intelligently with problems that will necessarily arise if he enters some industrial pursuit where chemistry plays some more or less important rôle? His thesis work has some of the elements that are necessary to train a chemist for this work, but usually the time devoted to this work is not sufficiently long and is too much broken up by other interests for the student to become thoroughly imbued with the spirit of research. What advantage is to accrue from the introduction of a course of lectures and a laboratory course in industrial chemistry? This question I can best answer after I have outlined the course; and the course I am going to outline is the one now given at the Worcester Polytechnic Institute. I do not mention this course to you as a model one, but it is a course which has, I believe, been of unquestionable value to the student, and which has gained some very desirable ends. At all events, I feel sure it is a step in the right direction.

First, let us consider briefly the work to be presented to the student in the lecture room. I believe the choice of subjects for discussion before a class should, to a considerable extent, be influenced by environment. Here in the East we have a number of industries wherein are exemplified the utilization of chemical principles. I have found that visits with classes to such places have been of the greatest value in driving home the facts that may have been presented in the lecture room.

On account of the fundamental relation that fuel bears to all industry, a discussion of this subject naturally comes first in a course such as we are considering, but it is omitted in our course inasmuch as a course on fuel and gas analysis, fully treating this subject, is given to both engineers and chemists. A discussion of sulphur is made the fundamental lecture; for sulphur, either free or combined, is the basis of the greatest group of chemical industries that exist—namely, the acid and alkali industry. In discussing sulphur, we study its occurrence, the devices used for obtaining it in a marketable condition, illustrating fully by diagram the mechanical devices used. In discussing not only this subject of sulphur but all other subjects as well, the museum of industrial chemistry is brought into requisition. This museum was founded for the purpose of illustrating the products, by-products, or waste products of the various factories as well as the various stages in any process of manufacture. A museum is a necessity. It is impossible to have all factories at convenient reach, while it is easy to have specimens which illustrate in a very satisfactory way the results of many processes which could be studied in operation only by visits to remote parts of our country as well as to foreign lands. For example, our museum contains a complete and carefully selected group of specimens illustrating the production of acids and alkalies. These specimens are so arranged as to exhibit the crude material and its various stages in development towards the finished product. This valuable set of specimens was presented to the Institute by the United Alkali Company of England, and is particularly valuable because this company uses the Leblanc process in manufacturing soda-ash, a process not as yet used in our own country. If the students can not visit the English alkali company, they can at least study very satisfactorily the results obtained by it in the graduated series of specimens in the museum.

Sulphur is the starting point of a great cycle of chemical industries; and naturally, following sulphur, we have the manufacture of sulphuric acid, which is the most important and widely used of our so-called mineral acids, and which is made from sulphur in either a free or combined state. Then we discuss salt-cake (Na_2SO_4) with its accompanying by-product, hydrochloric acid, and then soda-ash (Na_2CO_3), which is made from the salt-cake. In discussing the soda-ash manufacture, the main processes—the Solvay and the Leblanc—are thoroughly gone over, as is the Chance process for the recovery of sulphur from vat waste, which has been until recently, a waste product in the soda-ash production. This recovery of sulphur from vat waste completes the cycle of changes of the sulphur, through sulphuric acid, salt-cake, vat waste, and then back to sulphur, with the accompanying production of substances of much commercial value. In this "Great Industry," we must of course discuss nitric acid, which is made through the medium of the sulphuric acid. Hydrochloric acid, nitric acid, and sulphuric acid form the great group of commercially valuable acids.

Soda-ash is the starting point in the manufacture of caustic soda, so this industry naturally follows. Then is discussed the utilization of the hydrochloric acid, which is a by-product in the manufacture of salt-cake, for producing bleaching powder or chloride of lime. Here are discussed the two great processes—that of Weldon and that of Deacon. The dry distillation of wood and the purification of the valuable products formed, (wood alcohol, acetic acid, etc.,) make an important topic for discussion, as does the methods for isolating and purifying the valuable constituents of coal tar, (benzene, naphthalene, carbolic acid, anthracene, etc). The manufacture of glass is not overlooked, nor such important industries as the fermentation industries, the manufacture of starch, glucose, grape sugar, and dextrine.

These are about all of the topics that can be discussed in a short lecture course; but these subjects may be discussed with sufficient fulness for the student to grasp the details thoroughly. He is taught the chemistry of these processes and the means of applying these chemical principles to the end in view. The student learns the technique of the processes, and much stress is laid on the chemical principles involved and on the mechanical devices used and their manipulation. This study includes much detail, and progress is therefore necessarily somewhat slow; but it is much better for the student to learn his *half*-dozen processes thoroughly than his dozen incompletely.

In connection with this, I wish to bring to your attention a plan introduced last year with excellent results. The junior chemists, in their drawing course, devoted their time to making plans of machinery and mechanical devices used in chemical industries. This makes a first-class preparatory course for their work in industrial chemistry, which is taken during their senior year.

No single text book is used in a course of this kind. The best authority on the subject under discussion, is recommended to the class, and they are given whatever other collateral reading is necessary. The technical journals also form a very necessary adjunct to any course in industrial chemistry.

The laboratory work is as practical as possible and is so selected that it is of as diverse a nature as can be. To illustrate a sample of the laboratory work, one that is not of great difficulty but still illustrative of the method pursued, let me call your attention to the substance rock-salt. The student is told that this substance is too impure for a certain purpose for which it is to be used,—it must be made chemically pure before it is of any value for this purpose: how may he accomplish this end? This problem becomes to him a practical problem which involves the principles of a chemical research. He uses his knowledge of qualitative and quantitative analysis to find out what impurities are present in the rock-salt, and in what quantities. With this knowledge he is in a position to study the theoretical side of the question. After he has solved his method and it has been looked over and thoroughly discussed with him, it is given a practical test on a fairly large scale.

During this last year, a plan was devised for arousing and increasing the interest of the students of technical chemistry. Crude chemical substances or refined ones, as the case might be, were sold to the student at their market value, and these substances, after they had been worked over, purified or refined by the student, were bought back by the laboratory at a price determined by the purity, yield, and market value. This plan has proved so successful that it will be repeated during the coming year.

The student passes from one problem to another as rapidly as the ease of his problem will admit, until he has gone over the simpler and more obvious examples. It is of course to be understood that these problems are graded in difficulty, so that the student becomes, with the experience he has gained, much more capable of applying himself to the more serious and difficult problems which confront the manufacturing interests of to-day. At present the work is devoted principally to the solution of problems involving data selected from inorganic chemistry.

In connection with the work which has been mentioned and for the sake of diversifying it, the important question of the disposition of waste products and by-products is discussed and studied in the laboratory. For an example of a waste product, the student may have submitted to him a liquor which was, until recently, looked upon as of little or no value; but industrial chemistry has reclaimed the copperas from this waste liquor and it is used largely in the manufacture of Venetian red. Fortunately, we are so situated in Worcester that the student may be shown the practical utilization of this liquor, now no longer a waste product.

Besides the problems submitted to the student, he is given laboratory instruction in the manufacturing of chemicals on a large scale; that is, on a scale which is large as compared with that upon which the ordinary laboratory work is conducted. This form of instruction is adopted because by this means, the student learns the use of apparatus he may have had no occasion to use in any of his previous work. The knowledge thus gained is absolutely essential, inasmuch as such information must be used when dealing with problems relative to technical chemistry.

The course in industrial chemistry outlined here is capable of very great extension both in the nature of the subjects discussed in the lecture room and in the kind of laboratory work offered. One line of industrial work has recently so commended itself to the people of Massachusetts that it has resulted in the establishment of the Lowell Textile School. This school is but an extension of the study of industrial chemistry along the one particular line of "textile fabrics," and the study of such a subject in minute detail is valuable here in New England, because the manufacturing, bleaching, and dyeing of textile fabrics is one of New England's greatest industries.

I believe that work in industrial chemistry is such as will stimulate the student to original thought and thus exercise his highest mental faculties. Combined with this mental work, he has the opportunity of putting his ideas into actual practice; here he sees theory and practice exemplified; and I believe that no branch of chemistry has greater possibilities as a mental stimulus than the subject of industrial chemistry. The student's laboratory experience has helped to teach him how he must go about solving a chemical problem: for each problem given him constitutes a research of more or less difficulty; and there is no more valuable spirit to be fostered than the spirit of investigation. If this desire for investigation has been awakened in the student, surely a most valuable end has been secured, for the research laboratory is the head, and the works the hand of our industrial life.

If our technical schools educate the chemists to know certain of our industries well, and at the same time try to awaken a spirit of investigation, the result will be exceedingly valuable. Both of these desirable ends may be served by teaching industrial chemistry in our technical institutions, and this will aid in the rapid and wholesome advancement of our industries.

DISCUSSION.

Professor Bull said that he was greatly interested in the paper. He thought that, on the whole, education in technical or industrial chemistry has been shamefully neglected in this country. The speaker had had repeated opportunities to see the results of education in this line in Germany, as shown in the great success of the German chemical industry. He thought that no other country is so favorably situated as America to develop along this line.

Professor Ayres said that he also thought that the subject of technical chemistry is an important one for the technical schools, and that it had been neglected. He had had occasion to be interested in the subject in its bearing upon the manufacture of sugar in the State of Louisiana, in which sugar production is one of the important industries, the value of the annual crop being estimated in millions of dollars. Louisiana, however, produces a very small percentage of the sugar that is used in this country, that article being the largest import that we have. We are thus dependent largely on foreign countries for the supply; but there is no good reason for this, as there are large portions of the country which are available for the growth of sugar and which are not now devoted to that purpose. There are also large portions of the country well adapted to the cultivation of the sugar beet: and in Hawaii, Porto Rico, and Cuba the opportunities for development of the sugar industry seem almost unlimited. The speaker was impressed with the importance of giving further consideration to the chemical problems involved in the manufacture of sugar from the beet and from the cane. He said that in Louisiana it has come to be recognized that it is of the utmost importance to have a chemist in every sugar factory; and as these factories are of considerable magnitude, the salary of the chemist is saved many times over by the increase in the accuracy of the process of manufacture. But the planters have been forced to draw upon foreign schools for the greater number of their chemists. The speaker said that there were several of these chemists who had been educated at the Massachusetts Institute of Technology; his own institution, and one or two others, were trying to do something in this line; but the field is an enormous one. Another point that the speaker wished to emphasize was that the mere chemist does not meet the requirements. It is not sufficient to have only the training obtainable in the general chemical laboratory.

Men are needed who are preëminently engineers with a knowledge of industrial chemistry in addition; men who know not only how to make analyses and tests at the various stages of the process, but who can also design a sugar plant from beginning to end, thus insuring economical handling of the entire enterprise. The efforts of such a man may mean the difference between success and failure of the project. The speaker, in closing, said that he did not want to give to the sugar question more weight than was its due; but it seemed that, because sugar is so largely imported, and because vast fields have been opened up to us as a result of the war just brought to an end, that the industrial schools everywhere in the country should give this matter a large share of their attention.

Professor H. P. Talbot,* said it seemed to him that, in general, the best training that an industrial chemist can have is that which gives him the most of pure chemistry as a foundation, provided, of course, he should also, in some considerable degree, come in touch with the practical side of the science, as this is the point where instruction in technical chemistry is of importance. He thought that the tendency in laboratory instruction in general is to give the student a good deal of book knowledge, and also to limit his work to the handling of materials on a small scale, but it is in the industrial laboratory that he comes in contact with material by pounds whereas he has before been using it by grammes. The speaker thought that, while accuracy must be required from every chemist, yet he had seen men who, when they came from the quantitative laboratory, were too careful, and such men would be almost useless in practical business because they would waste time. It is in the industrial chemical laboratory that such a student learns to use his discretion and judgment and to get some idea of the conditions he will meet outside of the walls of the institution of learning; and this laboratory work is therefore of particular value to him.

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The speaker said that it had occurred to him, as Dr. Dunlap spoke of developing the power of originality, that that point could be strongly emphasized by those who wish to introduce technical study into a chemical course. He thought that there is on the part of the academical institutions, a possibly natural tendency to feel that the man that is in technical work is not on the same plane with the man that is doing investigation work in a university laboratory. This feeling is justified to some extent; but there are many industrial chemists that are doing a high grade of work, and a great deal of their work is as truly investigation work as that done in the purely chemical laboratory: much of it does not come at once to the surface, because it has to be kept temporarily in the background for commercial reasons, but it eventually goes to increase the sum of human knowledge. The interests of pure science are those promoted by the contributions from the side of the industrial chemists: and when we teach pure science with due regard to the student's future occupation, we are, in a measure, teaching industrial chemistry that is coming into play by and by.

PROFFESSOR F. H. ROBINSON remarked that there was a particular applicability in the closing remarks of Professor Talbot, as to the connection between the teaching of pure science and its application, and he thought that the faculty must sooner or later come to the point where a broad foundation of pure science will be found necessary in the teaching of industrial chemistry.

THE DIRECT STUDY OF THERMODYNAMICS.

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The title of the present paper, which, I fear, has carried with it little idea as to what is to be the subject-matter presented, was chosen in order to lay especial emphasis upon the word "direct," as contrasted with the idea of an "indirect" method of study. It is the general purpose of the paper to show that the method of teaching the science now most commonly in vogue is indirect, and that a more direct method is available.

That the indictment of the usual method as indirect may be not misunderstood the following brief outline of its course is submitted for consideration. It is intended to be as fair a sample as possible of what is considered objectionable and to show that the indictment is directed against the general compass-course of the method and not against any minor points of class-room peculiarities of individual instructors.

In the present method of teaching thermodynamics, as outlined in most of our text-books, the student's attention is first drawn to the thermal properties of matter in general. This is done with a view to familiarizing him with the idea of heat through its manifestations. But, in the first place, this is ground all of which he is supposed to have covered in his study of physics. And secondly, if heat is to be comprehended only through the medium of its manifestations, the selected phenomena which are to serve this purpose should be thermodynamic phenomena, not any thermal phenomena; and they should be presented in their proper place. How both of these conditions are met in the course advocated herein can be understood only from later developments.

The student is next given a series of "laws of thermodynamics" to be memorized, in which are expressed the magnificent and ubiquitous elementary principles of the science in three paragraphs of lawyer's English about as inspiring to his imagination as is the average geometrical theorem.

He is next introduced to the relations between pressure and volume for the permanent gases,—Mariotte's and Gay-Lussac's laws, isotherms, isobars, adiabatics, and all the rest. The somewhat complex equations expressing these changes and the external work done during them, are discussed by means of the calculus, which is used more or less recklessly according to the instructor's distance from contact with the world of actual engineering instruction. And yet, before the course is over the student has to be told, if he does not know it already or has not been wonderingly conscious of it all of the time, that the permanent gases are very seldom used in heat-engine operation and that all the members of that class form a very insignificant fraction of the heat-engines of the world. This being so, I urge as axiomatic that their consideration, instead of constituting an introductory elementary feature of the course, should be reserved to the last as a fit embellishment for the refinements of its later development.

Next comes the idea of the cycle. For its illustration is used the Carnot cycle, working with air, and exhibited by means of the pressure-volume diagram. The objections to this are that air is the one substance for which the Carnot cycle is hopelessly impracticable, even in the hands of our friend Mr. Diesel; and that the pressure-volume diagram, with its hyperboloidal isotherms and adiabatics, is the one diagram in which the essential phenomena of the cycle are invisible and the essential quantities are to be expressed only by passing to infinities.

Finally the student is introduced to the properties of steam, and then to the steam-engine cycle as the least efficient of them all and the most to be despised from a theoretical standpoint. If the use of the calculus were free and easy before, it is run mad now, and pages of double integrals give the student the idea that there must be some direct relation between superheated steam and the passage of the English Channel. But he comes out of it all right, for he finally learns that not even the highest of mathematicians can exactly express the complexity of most of these changes, and that the only way to do in active life,—for every engineer does it,—is to forget all of this intricacy and fall back upon steam-tables and rules-of-thumb.

Out of such a jumble as this I came, from a good instructor in a good school, with almost no one definite idea regarding thermodynamics. I have heard several teachers in this science complain that they had to spend more time teaching calculus than they could devote to thermodynamics. And I well know that the average student and the average engineer of my acquaintance regard thermodynamics as the most headless, tailless, soulless, and profitless bugbear of the whole engineering course.

Now I do not believe that this is either right or necessary. I should regard my life as a teacher as a total failure if my students regarded their work under me thus, and promptly forgot what I had told them when once they left college. Fortunately, before I was called upon to teach thermodynamics I had had time to forget all of it that I ever knew. And having to study up afresh a practical method of exact thought and simple presentation in the science, I have been able to see plainly how completely and atrociously the above method is the exact reverse of the natural method of approach to the subject. I have seen that this reversal consisted of presenting elementary axioms as secondary corollaries, at the eleventh hour instead of the first; of filling the student's mind at the start with a lot of facts which are absolutely irrelevant to the pure science, and which come in only as modifications in its applications; and of so failing to found the science upon what the student already knows and is familiar with, that only he who has mastered the intricacies of the science and broadened his view by years of use of them, can possibly have that clear comprehension of the subject which is based upon simple perception of the relation between heat-engines in general and the other things of daily life which go to make up our idea of the universe and the way in which it moves and has its being.

It is in the effort to substitute for this a more natural method of approach, which should teach the pupil a few strong, elementary ideas regarding the science which he should find of daily use to him and which he could never possibly forget, that I have substituted for it in my own work what I shall here refer to as

THE DIRECT METHOD OF TEACHING THERMODYNAMICS.

The basic idea of this method is that the study of thermodynamics is purely one of energy-transformations. While in a problem in mechanics purely kinetic considerations may arise as the controlling factor in its solution, in thermodynamics this is never so. The alteration of thermal into mechanical energy is always the essential problem: and almost always the efficiency of the transformation is the prime unknown or guiding factor in the discussion.

This being so, the student's attention is from the start concentrated upon the reality of energy, the conception of quantity of energy and the familiarization with its several common forms. This has probably already been done, to a certain extent, in his study of physics. But now the subject is brought up to him again, not only in review but in a new light,—these forms of energy being presented to him as the tools of his life's trade, the skillful handling of which is to constitute the object of his every professional endeavor and with whose every aspect he must become thoroughly familiar. In fact, in any line of engineering study students should always be taught, as I have always found in my engineering experience, that the only way to think clearly through any actual problem is to habitually *think in terms of energy.*

To this end the forms of energy are first roughly classified as:—

Chemical: Potential.
Electrical: Potential and kinetic.
Mechanical: " " "
Thermal: " " "

Each form is clearly identified in the student's mind and its units of measurement recalled or defined.

His attention is next centered upon the fact that these forms are all interchangeable; that as forms they are exceedingly evanescent, but that as quantities they are eternal; that a definite quantity of one always reappears as a definite quantity of another, merely the outward aspect being altered. He is made to devise or recall instances of such transformation between each pair of forms, in either direction, and to perceive the frequency and facility of the majority of these transformations in the universe about him. In every way possible he is taught to realize that the underlying identity of the energy undergoes no more alteration than does that of the actor on the pantomimic stage during a lightning change of costume. Moreover, he is trained to see, as an important feature of accurate engineering perception, that whereas the bulk of the energy of the universe is potential in form it is the kinetic or vibratory forms alone which appeal to any of our senses.

In this way the student comes upon the First Law of Thermodynamics, not as a strange and abstract paragraph which stuns his imagination as a blow on the head might his wits, but as a local habitation and a name for an eternal and all-pervading idea which he has learned to recognize in its manifestations in every department of life.

The next step in the course is to call the student's attention to the fact that each of the above mentioned forms of energy, whether potential or kinetic, can be measured, as to quantity, only in terms of two factors, such as height and weight, mass and velocity, voltage and amperage, etc. One factor of each pair is then identified and defined as the factor of *intensity*, the other as that of *extent*,—for want of better terms. The classification of these factors can be seen in the accompanying table.

TABLE I.

FORM OF ENERGY.		Factor of Intensity.	Factor of Extent.
Mechanical:	Potential....	Distance	Force.
"	Kinetic	Velocity	Mass.
Electrical:	Potential.....	Volts	Coulombs.
"	Kinetic. ...	Volts........	Amperes.
Chemical......		Affinity	Mass.
Thermal, Both Forms ..		Temperature	Entropy.

Attention is then directed towards the universal tendency of all forms of energy to *run down in intensity*, from a higher degree to a lower, whenever the chance presents itself. Thus, weight always tends to move from a greater to a lesser degree of separation from the earth; moving masses always tend to impart their energy to masses having a lower velocity; chemical combinations always tend towards the more stable unions; electrical currents always flow from higher to lower potentials;—and never the reverse. This tendency is pointed out as characteristic of all natural phenomena and as constituting one of those basic facts of the universe, the full comprehension of which is as useful to the engineer as is that of gravitation or elasticity.

Conversely, we have the equally universal proposition that no form of energy can spontaneously raise itself from a lower to a higher degree of intensity, except by some intermediate double transformation through other forms; nor can it be so raised (without this intermediate transformation) except by an addition of energy from some external source. Thus, weights can be lifted by external power, or a large weight on a low lift will raise a small weight by a large lift by means of interposed apparatus and energy-transformations; or electric currents can be driven from a low potential to a high one by means of a dynamo driven by external power; or by the interposition of a transformer and its complex activities a large low-potential current will produce a smaller high-potential one.

In this way does the student meet, and welcome as a familiar reality rather than a vague abstraction, the Second Law of Thermodynamics.

These broad doctrines are not irrelevant to the study of thermodynamics, because it is the lack of them heretofore, the lack of any living flesh of human experience over the dry bones of isopiestic curves and logarithmic functions, which has made thermodynamics so unintelligible to all except mathematicians and as comparatively useless in the daily walks of life as was the purely anatomical geometry of a century ago.

For, if we turn back to steam-enginery, we find that the source of its power, as of all other powers useful to man, lies in this universal tendency of all energy to run down-intensity,—or in this particular case, of heat to run down-temperature. For the intensity-factor of heat *is* temperature, and the well-known tendency of heat to flow from a hot body to a cold one, and never the reverse, is neither a dissimilar nor in any wise less irresistible a power than is the rush of water from the mountain to the sea or of the electric spark from the tremendous voltage of the thunder-cloud to the low potential of the earth's crust. It is this basic conception of the power behind the throne, of the real reason why boilers burst and cannon-balls fly, of why lightning strikes, acids corrode, and floods destroy, as well as why wheels go around; of the utter simplicity and unity of the explanation of these mysterious and apparently dissimilar phenomena,—it is the knowing of this primary fact of nature as one knows his alphabet that constitutes the difference between the engineer and the mechanic. And it is such a clear and basic conception alone which can raise the study of thermodynamics to a position where the student will carry away from it, out of college and all through life, a real help in the daily earning of his daily bread.

This broad approach to purely thermodynamic phenomena is not only advisable for general reasons but becomes absolutely necessary when we remember that, while the two factors in the measurement of nearly every other form of energy are either plainly perceptible to the human senses, or else, although abstractions, are already long familiar to the student, yet of the two factors of thermal energy only one is an at all familiar idea of a sensible thing. Temperature, the factor of intensity, we can know as a thing to be felt by the hand, an idea so easily grasped that it enters our lives in early childhood. But entropy, the factor of extent in thermal energy, is a thing which cannot be apprehended by any of the five senses. It is an idea so abstract that it has hitherto been relegated by teachers of thermodynamics to an advanced position in the course, as an ultimate refinement of synthetic discussion rather than a primary element in analytical comprehension of the science. But when the fact is recalled that entropy is one of only two factors without which heat can not be measured the attempt to dodge the task of comprehending it until the course be nearly finished becomes obviously absurd; and like all other evasions of natural difficulties in hopes of making things easier, this one has always resulted in unnecessary complexity and labor in the presentation of the science and in confusion and dissatisfaction on the part of the student.

But as any definite idea of entropy can be had only by analogy, the approach to the science which I have just described has been devised in the hope of plainly illustrating to the student the proper place in nature of the several conceptions of entropy, of heat, and of the heat-engine.*

The above is the gist of what I have to say. Yet you will get a much better idea of its significance if it be brought down to earth by an outline of the further steps by which the student is given, first, the details of the pure science, and secondly, those applications which shall finally land him in possession of a complete equipment for thermal engineering.

It is first pointed out that the tendency of heat to run down-temperature would result, if unhindered, in each lump of heat precipitating itself to the absolute zero of temperature, reappearing to our perceptions wholly converted into its mechanical equivalent. The first hindrance to this tendency is noted in the absence of any place for it to run to, of any temperature-levels below those with which we are familiar. The second hindrance lies in the paths which it must follow in its fall.

To illustrate this, the two factors, temperature and entropy, intensity and extent, may be arrayed as rectilinear co-ordinates. On any such diagram quantities of heat must be represented by areas; and if any point, as A, Fig. 1, represent the temperature and entropy of a given quantity of heat, that quantity will be measured by their product, or by the area enclosed by abscissa, ordinate and axes. On any such diagram an isotherm must be represented by a straight horizontal line, and an adiabatic by a straight vertical line; and this representation of the adiabatic process is the only one which I ever knew to give the student a clear conception of the actual phenomenon.

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* The order of arrangement of Table I illustrates the order of procedure in attaining this conception, passing from the most familiar ideas, those of distance and force, to the least familiar one, that of entropy.

From these two simple ideas alone a complete and clear conception of the Carnot cycle can be built up. It is represented, of course, by a rectangle, as in Fig. 1. Here OA is the original quantity of heat with which the cycle is started; AB is the adiabatic down which it tends to fall; b is the point where this process is interrupted by the lower limit of temperature; bD_1 is the line of isothermal exhaust, interrupted at d by natural limitations; dc is the most efficient path for the return of the remnant to the upper level CA for a second load of entropy; and cA is the amount of entropy (DA being the amount of heat) necessarily taken in in preparation for it. The expressions for the efficiency of the Carnot cycle, and for the proportion of exhaust to live heat, follow almost axiomatically from the simplest geometrical considerations.

Any variation whatever from the Carnot cycle can be represented by such lines as mn or ts. It is easily shown that any such variation must represent a "free fall" of the entropy either into or out of the cycle, and that it is always accompanied by a loss of efficiency measured by the lost area; for the heat consumed is given by the area *DmnAB*, the work done by *mnAbst*.

I believe that I am safe in saying that this simple diagram, aided by such homely analogies as the filling and emptying of water-wheel buckets, etc., etc., will carry to the student's mind a clearer idea of the performance of mechanical work by the cyclical fall in intensity of other forms of energy, and of heat energy in particular, than can be approached by any method involving the idea of a working-substance and its pressure and volume. The idea comes to him, not as an abstract and intricate proposition to be demonstrated mathematically, but as a broad, natural phenomenon whose laws are too obvious to be overlooked, too universal to be broken, and too simple to be confused in any of the complications and limitations of actual practice encountered later on.

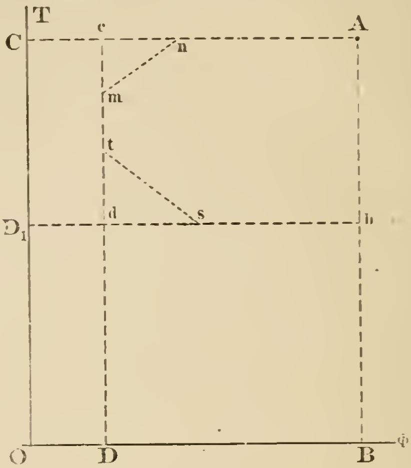

Fig. 1.

Without any delay the student is next introduced to the reversed cycle, or refrigerating machine, in its abstract, Carnot-cycle form. Not only does this strengthen his elementary grasp of the principle of operation of the heat-engine, but it forever places, beyond possibility of removal, the refrigerating machine in its proper relation with other things.

The Carnot cycle having no actual representative, the next step in the course is to introduce the student to the cycles of existing types of engines. It is most natural to begin such a transition with those cycles exhibiting the smallest departures from the Carnot. This would place, with a single unimportant exception, the steam-engine cycle in the van. It is consequently and most naturally taken up first.

It is to be noted that up to the present moment no mention has been made of a working-substance. For the study of even the theoretic cycle of any heat-engine other than the Carnot the thermal properties of the working-substance necessarily enter as modifiers: hence attention has to be given here to the thermal properties of water. The steam-table is taken up and the different kinds and quantities of heat discussed in terms of the different forms of molecular energy which they represent. Assuming the imaginary heating of water from the temperature of melting ice, the diagram shown in Fig. 2 is developed. A necessary preliminary to this is the development of the general entropy-temperature equation for the heating of any substance: and in its derivation appears all of the calculus which enters the course. The line O_1Ab represents the law of simultaneous increase of entropy and temperature during the heating of water from the freezing-point to boiling, under atmospheric pressure at A and under 100 lbs. gage-pressure at b. At any point z the amount of heat absorbed, dQ, in an infinitesimal rise of temperature

$d\tau$ must be the area of the elementary strip down to the horizontal axis, or $\tau\, d\phi$. It is also equal to $m\, d\tau$, where m is the specific heat of the substance heated, no matter what its physical condition or surroundings. From the integration of this equation, $\tau\, d\phi = m\, d\tau$, comes the general equation for the heating of any substance: $\phi = log_e \frac{\tau}{\tau_2}$ where τ_2 is the original absolute temperature of the body in question.

This simple logarithmic curve, with the horizontal isotherm and the vertical adiabatic, covers all of the thermal processes occurring in any of the heat-engine cycles yet known to me.

The derivation of the expression for an area under such a curve, as *Aba*, is the only other use made of the calculus during my undergraduate course.

The meaning of this will only be evident after considering some of the cycles in question. Without burdening you with detailed explanations which would doubtless be superfluous to most of you, allow me to point out that, in Fig. 2, the steam-engine cycle is shown by the dark area *AbCD*. As the Carnot cycle for the same temperature-limits is the area *ABCD* it is evident that the steam-engine cycle is a very close approach to the Carnot; its ratio is usually 90 to 94 per cent. This is a very much closer approach than that of Mr. Diesel, who started with the express purpose of constructing, as nearly as possible, a Carnot cycle. This diagram knocks at a blow the confused idea so often prevalent amongst engineers that the latent heat of the exhaust-steam is a source of inefficiency. At the same time it reveals as no other diagram can the real source of the inefficiency of the steam engine,—or it would, had it been continued upwards far enough to include the highest temperature of available heat, or the 3000 degrees absolute of the furnace-fire. Were the scale at the left carried up to this figure it would be seen at a glance how small a proportion of the total height of the diagram,—the total "fall" theoretically available, and that necessary to convert all of the heat into its mechanical equivalent,—is the height *BA*, which is the fall available in the ordinary steam-engine.

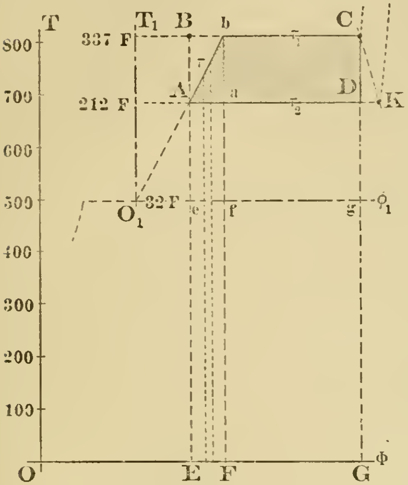

Fig. 2.

In this diagram, too, are visible to the eye many other things of interest and value. The area *Aba* shows the energy available from hot water, as in a boiler explosion; the proportion of steam resulting therefrom is that of *Aa* to *AK*; the proportion of water resulting from the expansion of dry steam at *C* is that of *DK* to *AK*, etc. But the soul of it all is the ready, clear, and mathematically accurate comparison with the corresponding Carnot cycle represented by the circumscribing rectangle, and the correspondingly clear conception of the paths open and the paths closed to the improvement of heat-engine efficiency.

Thus, Fig. 3 illustrates the Stirling, or regenerator, cycle. Here $AbcD$ is the cycle, composed of heating in the regenerator, Ab; isothermal expansion, bc; cooling by regenerator, cD; and isothermal exhaust, DA. The corresponding Carnot cycle is $ABCD$. Since the curves Ab and Dc are horizontally equidistent this cycle is equal in area and efficiency to the Carnot. Its small capacity for work, however, is fatal, and is shown by the slimness of the diagram.

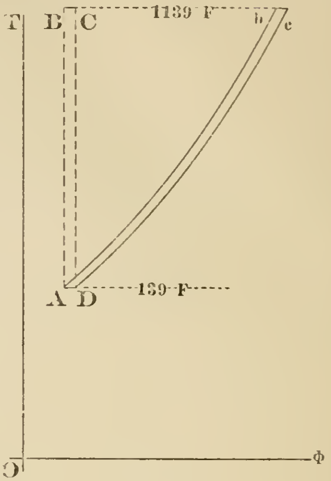

Fig. 3.

Fig. 4 shows the Lenoir and Beau de Rochas, or Otto cycles. Adc_1d_1A is the Lenoir, and $AB_1C_1D_1$ its corresponding Carnot rectangle. The Otto cycle, however, starts off with the familiar adiabatic compression, Ab, before firing, and gets the area $AbcdA$ as the result. Its corresponding Carnot rectangle is $ABCD$. Both of these are obviously very poor affairs as cycles, but the much greater temperature-fall which they cover, as compared with steam, give them a better final net result.

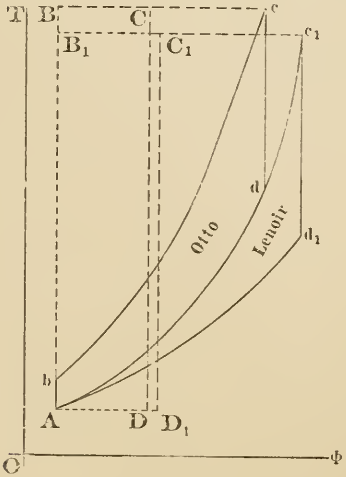

Fig. 4.

Fig. 5 shows the Joule cycle, of which type actual examples are the Brayton, the Gardie, the Diesel, and, still more recently, the Burgher, engines. The cycle is given by the area $Ab_3c_3d_3A$. Its corresponding Carnot rectangle by AB_3C_3D. It is obvious, from its fatter appearance, that this is more efficient and promising than the preceding two; but to make it the more evident I have drawn in the dotted lines bc and Adc_1, upon which the letters correspond to similar ones in Fig. 4. Fig. 5 shows very plainly, in this way, how the Joule cycle covers almost all of the available area of the Beau de Rochas cycle, nearly one half of that of the Lenoir, and an additional area of its own, bb_3c, which neither of them can touch. It is for this reason, in part, that the author has for years been advocating the construction of a modern engine upon this cycle. It is largely owing to his use of this cycle that Mr. Diesel owes his success, though also largely to the tremendous working pressures which he has dared to undertake. It is to this cycle that a continuous and steadily increasing line of inventors have been turning in their natural efforts to obtain release from the intolerable limitations of the Otto cycle.

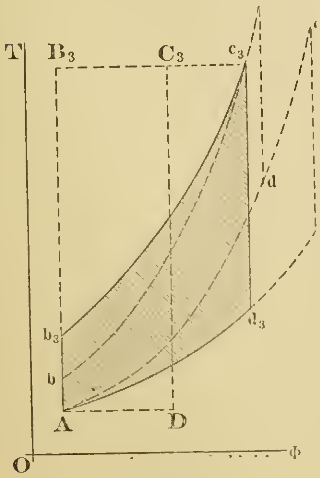

Fig. 5.

That these diagrams show that the last word has not yet been said upon the subject of efficient heat-engines, and that no others can equally serve to guide the engineer through the mysterious and untrodden paths of the future applications of thermodynamics in the efficient production of power, I cannot urge with greater eloquence or emphasis than that carried on the face of their own simplicity and directness towards the question of the day,—efficiency. But as to their offering the only true method of teaching the elements of a clear and accurate conception of thermodynamic principles I should like to say a great deal more than is possible within the limits of so brief a paper.

It might also be relevant to the subject to say that after the departure of the student from the realms of pure thermodynamics, in his next term's work in steam engineering, every student present is required to trace within these theoretical cycle-areas the diagram actually traced by a steam engine under his own hands and of which he himself has taken all of the records. He is obliged to compare this actual diagram with the theoretic one analytically, scheduling all of the losses exhibited between the two as to amount and, as far as possible, the cause of each. He also compares it with the corresponding Carnot cycle.

If his own special inclination leads him to take up gas-engine work for his thesis, or any other type of heat-engine, he must analyze the engine's record in the same way. I believe that the Railroad Gazette for this or the following week will publish a pair of such diagrams from a 100-H. P. Crossley-Otto gas-engine taken by three members of the class just graduated.*

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*See *Railroad Gazette*, August 2[illegible], 1888.

In all of this work, both pure science and applications, the pressure-volume diagram and equations are never discarded nor neglected. But they are always kept in a secondary position, as a sort of foreign language into which all of our thermodynamic thoughts have to be translated in order to communicate with pistons and cylinders; and the preliminary thought, to be clear and certain, is always retained in the native tongue of thermodynamics,—the rise and fall of entropy up and down temperature-levels.

DISCUSSION.*

Mr. Kent said that in connection with Professor Peabody's statement that entropy is a name for a function, he wished to ask if it is not a name for a quotient; namely, the quotient arising from dividing the quantity of heat or energy by the absolute temperature. The speaker said that he could not get hold of a conception of entropy in any terms or units of measurement known to man. He had also the idea that "mass" is the quotient of weight divided by the acceleration due to gravity, $\frac{w}{g}$ being a very convenient tool for the engineer to work with.

Professor Reeve said that his reply would not refer to the mathematics of the question, as that was largely a matter of opinion. He wished to state that the gist of his paper could not be understood except in this way: that the diagrams shown in connection with the paper are all supplemented by pressure-volume diagrams in the course of construction. Any cycle might be represented by twenty of the latter, according to the working-substance employed: but there is only one entropy-temperature diagram for each cycle. The entropy diagram represents a law; the pressure-volume diagram, an isolated fact; and no student can get a proper appreciation of any science without studying laws before facts. In regard to entropy, the speaker said that it is a real thing—as real as anything which occurs in the universe; and that no man can step into unknown territory until he has just as real a conception of entropy as he has of mass. The speaker desired to say further, in the interest of science, that as long as a man has a no more realistic conception of mass than as $\frac{W}{g}$ he can not possibly understand mechanics; and that as long as one holds a no more realistic conception of entropy than as a mathematical function, $\frac{Q}{T}$, he can not possibly understand thermodynamics.

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* The discussion was opened by Professor Peabody; but no adequate report of his remarks was secured, the stenographer being temporarily absent.—Editors.

Professor Galbraith desired to call attention to one point—The $\theta\phi$ diagram of the Carnot cycle is a rectangle, whatever be the nature of the working substance; thus the form of the diagram is independent of the peculiarities of the working substance which is not the case in the *pv* diagram. This is an advantage in discussing the properties of the Carnot cycle. In using the diagram it is not necessary that a student should puzzle himself by thinking about entropy. It is quite sufficient to recognize that the ordinates represent absolute temperatures and the areas quantities of heat. These are the only ideas essential to the use of the diagram. As he becomes more familiar with the diagram he may find it convenient to term measurements along the abscissas differences of entropy; the conception of entropy is thus naturally introduced as a convenience and not as a necessity. The speaker acknowledged that in common with a great many teachers he used the pv diagram, and made but little use of the $\theta\varphi$ coördinates, he felt that the paper would do good in inciting teachers to occasionally stray from the well-worn paths of the ordinary text books.

Professor Adams thought that there were some points in the paper and in the discussion that go beyond the subject of thermodynamics. He expressed interest in the different conceptions of the terms and quantities; and, in reference to Professor Peabody's inference that because it is impossible to get an accurate conception of temperature and of entropy, it is best to shun these things as much as possible, the speaker said he thought we have little *accurate* conception of any of the common forces of nature, e. g. mechanical force, any more than that we recognize them by their effects. He thought that it is only by analogy with familiar quantities that unfamiliar ones can be presented to us in such a way that we can appreciate them. The speaker thought that diagrams are useful because they give us some mental picture by which we can understand, if only in part, these new quantities or forces which are at first entirely foreign to our senses.

With reference to Professor Peabody's remarks on the limits of the utility of analogy, the speaker remarked that that difficulty is one that Maxwell overcomes by carefully pointing out the limitations of the analogy which he draws between heat and electricity. Analogies, like all other good things, should be used and not abused.

THE TRAINING OF ENGINEERS FOR THE MAINTENANCE OF WAY DEPARTMENT ON RAILROADS.

BY J. C. NAGLE.

Professor of Civil Engineering and Physics, Agricultural and Mechanical College of Texas, College Station, Texas.

In the United States there are at present about 240,000 miles of railway track, all told, and the importance of keeping this in thorough repair can not be overestimated. Thorough discussion of the subject should aid in bringing about a better understanding of the best general methods of attaining this end.

If we may judge by the meagreness of the literature on the subject, track work has not so far received the attention from engineers that it deserves. Indeed, many railways entirely divorce the work of track maintenance from the work of their engineering department and place it in charge of the operating department. This is manifestly in opposition to the best interests of the railways—or at least would so appear to an engineer. Tratman, in his excellent book on "Railway Track and Track Work," calculates that the maintenance of way of railroads in the United States costs twenty per cent of the total operating expenses—or nearly fourteen per cent of the total revenue derived. Surely the expenditure of such large sums as this involves should call for men specially trained in matters bearing thereon.

That the direction of work connected with maintenance of way should be under the supervision of the engineering department needs no discussion. The question simply reduces to this:

Should engineers and other officers of maintenance of way receive special training for their work, and if so how can this training best be secured?

Our technical schools are prepared to give general training along civil engineering lines, but so far as railway track work is concerned, it has thus far been general only. Of course the underlying principles necessary for the understanding of all engineering operations must be given, together with such laboratory and experimental work as will familiarize the student with the uses and strengths of materials of construction; but no institution, as far as I know, has as yet made any very extensive effort to familiarize students with the many details of track and track work. This is not true of bridge engineering, for example, nor of hydraulics, nor of sanitary engineering, etc. In mechanical engineering, extensive shop and laboratory equipments enable the student to become familiar with many details and mechanisms employed in practice, and at some institutions enable him to make experimental tests of even the largest locomotives.

As regards the details connected with maintenance of way, it is difficult to secure even descriptive literature, to say nothing of experimental knowledge of the subjects treated.

At the January meeting of the Western Railway Club, Professor W. F. M. Goss advocated equipping engineering schools with experimental tracks, upon which various systems of railway maintenance might be employed for short lengths of road, and pointed to the success attendant upon the use of shops and laboratories in mechanical engineering.

That the subject should be carefully treated in our engineering schools is unquestioned; but that the method suggested by Professor Goss would yield conditions comparable to those actually existing in practice is extremely doubtful, and the most that could be accomplished would be to make the student familiar with some track details and appliances — which of course would be valuable, but scarcely sufficient to warrant the heavy expense that would necessarily be incurred. Until some better plan has been proposed I shall believe that the young engineer can best become familiar with this class of work upon railways in actual operation; and thus far he has had to do so more by observation than by intimate association with the work itself. So long as roadmasters and division superintendents are drawn from the uneducated and technically untrained section foremen, who themselves have risen from the lower ranks of the track force, there must be more or less rule of thumb work and many unnoticed leaks. The day of the so-called practical man must soon pass and he must give place to others who couple with their practical knowledge a training in the fundamental principles upon which true economy dictates that their work should be based.

On the other hand, a theoretical engineer might, if placed in charge as roadmaster or division superintendent, prove a failure for lack of detailed knowledge, and from inability to so direct work that every little detail should be handled economically.

What, then, should be the qualifications of division superintendents and other officers directing work on maintenance of way?

Clearly they should be men who couple with the necessary technical training the intimate personal knowledge that comes only from having worked in the capacities that their subordinates occupy. Men so trained will not be so overbearing, so tyranical and inconsiderate, as the uneducated men who have been elevated above their fellows; nor will they be likely to demand too much through inability to measure exactly the capacities of their subordinates. I do not think the plan proposed by Professor Goss would accomplish the purpose aimed at, because sufficient time could not be given to the subject in the college course, nor could the student be expected then to do the amount of manual labor necessary to acquire the desired knowledge of details. There should be some plan by which the student would at some time have to serve in the various capacities of laborer or track walker and as section foreman, then as roadmaster's clerk, and finally as roadmaster. Later on he might, if qualified, be made a division superintendent. In passing through these various stages he would secure a knowledge of every detail of his work that can be gotten in no other way, and yet he would be broad-minded enough to discern the weak points in the systems practiced, and from his technical training he could work out a more or less complete remedy.

It may be of interest to insert here a letter that I wrote to the Railroad Gazette, which was published in that periodical, in the issue of March 18, 1898. This letter gives a brief description of a method inaugurated on a road whose officials recognized the defects in the systems now in vogue. If this method were systematically carried out it would serve every desired purpose. I repeat the letter in full:

College Station, Tex., March 2, 1898.

"To the Editor of the Railroad Gazette:

"Referring to the remarks of Professor W. F. M. Goss before the Western Railway Club, published in your issue of Feb. 18, I would like to mention, in addition to what he says concerning the value of a track laboratory, another reason why civil engineering graduates do not accept low positions in the track department on railroads, and that is that as our railroads are now conducted there is no hope held out to them that they will eventually be advanced above the grade of common laborers should they prove deserving—at least they would be given no preference over the uneducated trackmen with whom they would be associated. Too often college graduates overestimate their abilities and the value of their technical training and are apt to feel that their diplomas should be warrant enough for seeking at once the higher positions. If their instructors, however, would impress upon them the importance of an intimate knowledge of details and would give them to understand that the real value of their technical training lay in the advantage it gave them over their less fortunate fellows, by enabling them the more readily to fit themselves for higher positions, I think there would be no lack of such young men willing to take any position, however humble, that offered opportunity for advancement.

"It may be of interest to mention an experiment that has been tried along this very line on the Southern Pacific Railway in Texas. The following letter is one of several received from Mr. E. B. Cushing, M. Am. Soc. C. E., Resident Engineer S. P. Ry., during the spring of 1894, and will explain the plan, which originated with him:

'We propose to establish on the line of the Southern Pacific a system of apprenticeship in the track department, the plan being to furnish employment for about a dozen young engineers in the capacity of track walkers. The duties of a track walker are to pass over certain portions of the road (from three to ten miles each day), to keep tight the bolts and to report any defects in the track which he cannot repair. He has to lend a hand with tools when necessary and to assist in general section work, when not on his daily walk. The track walker is regarded as an assistant foreman, and we propose to pay these young men $1.85 per day. Such as are worthy will be promoted in the proper time to section foremanships and will be given preference for promotion to vacant roadmasterships or assistant engineerships in the track department when qualified for such positions.

'Our idea is that in this way we shall not only secure roadmasters (and perhaps superintendents) thoroughly versed in the construction of the road and its maintenance, but will also furnish the engineering department with assistant engineers who know practically, as well as theoretically, all the features of this department. The work will of course be hard and we do not hope to have all who undertake it follow the lines laid down, but that out of a dozen we may secure three or four who will remain with us until they can reap the reward of their apprenticeship.

'You will see, therefore, that this is no place for society men or young men who expect to be chief engineers within a few months, but that there is an opening for those who really wish for advancement in the railroad service. Our experience has taught us there are very few of the large number of engineers applying for positions who are of any service beyond the mere instrumental service in their professions.

'I hope that the idea may strike you as a good one and that you will assist us in procuring these young men when needed.'

"My civil engineering students took kindly to the proposition from the first and there were more applications than openings. Those who were accepted went to work as section hands and were assigned to sections in Western Texas, where they worked side by side with Mexican laborers. If I am not mistaken they were paid $1.50 per day at first, instead of $1.85, as was originally intended. As opportunity offered they were transferred from one position to another so that they might become thoroughly conversant with all branches of the work, and so far as I have heard they all remained with the road in spite of the hardships encountered. Only a few had been employed, however, before Mr. Cushing accepted the position of General Superintendent of the H. E. & W. T. Ry., and with the change in officers on the Southern Pacific came a change in policy, so that the same inducements are no longer held out to our young men. Recently I wrote to Mr. Cushing to ascertain how he had regarded the results of the experiment and in reply he states that as an experiment it was eminently successful, as far as it went. I quote from his letter of February 26, 1898:

'I obtained permission to inaugurate the system and placed four young engineers on the road as laborers, from which positions they, by their own merits, worked out their own promotions and three of the four became section foremen. One is the foreman of a large extra gang and is giving the best of satisfaction; two others are still working as foremen and giving satisfaction, whilst the fourth, by his own merit and attention to business, attracted the attention of a large contractor, who offered him a position far more remunerative than he could hope to have for some time, hence he left the service. Thus you see that as far as the experiment went it was eminently a success.

but a move of this kind will always meet with opposition from certain sources, and these young men labored under serious disadvantages, and the extent of the opposition was such that the plan is no longer carried on in the maintenance of the way department. I have never changed my opinion that such a training as this, based on a thorough technical education, was the best qualification for responsible positions in the railroad service.

'I found no trouble in obtaining young men ready and anxious to work in these humble positions when they felt that they had assurance of promotion should their work merit it. Furthermore, I have always found that engineering graduates are anxious and willing to work in subordinate positions in engineering corps, and that they give better satisfaction as a general thing than the other men employed in this capacity.'

"If any experiments have been tried elsewhere along this line I should be glad to learn of their results."

Commenting editorially on the plan outlined above, "The Railway and Engineering Review," in the issue of March 26, 1898, contends that the student should have had the practical training before taking up his college course. If we remember, however, that few students entering college are old enough to have been physically able to do such work, the impracticability of this latter plan is evident. Moreover, since the mind is most receptive at the age usually allotted to college work, it would be wasteful of time and energy to require a young man to postpone the period of mental training until after having attained the physical development necessary to enable him to secure practical training as section hand, track-walker, and foreman. Among eighty young men who have graduated from our civil engineering course during the last eight years, I know of only one who has been through even a part of the course suggested by "The Railway and Engineering Review." On the whole the plan mentioned in my letter to "The Railroad Gazette" would seem to offer advantages superior to any so far suggested, provided it could be more generally inaugurated and honestly carried out.

Two other possible methods of securing the same results occur to me, but there are objections in the way of both.

One way is for our technical schools to arrange with our railways to give employment—either as track-walkers or as track laborers—during their vacation from college, to those of our engineering students who wish to qualify themselves for track work. For their services the young men might, if deserving, receive some slight compensation; or if there were some definite prospect of future employment in more advanced positions I think there would be no lack of young men willing to work for one or two summers merely for the sake of the experience. After graduation they might be given employment for a time with the engineering corps, or as assistant foremen, and if they should prove to be deserving they could then be advanced to higher positions, either as engineers or as roadmasters and superintendents, as vacancies might occur. Some might be required to serve as foremen for years before being advanced, but there are many young engineers who are glad to work for less salary than a section foreman receives. With men trained as suggested there would not be the social ostracism and prejudice that is sometimes manifested toward men occupying subordinate positions on railroads.

The other plan to which I refer is for each engineering school to arrange with some neighboring railroad to have placed in charge of an engineering instructor connected with the institution, short sections of track to be kept in repair by relays of students, aided by such additional workmen as might be needed should the engineering classes be too small. Upon such a section various kinds of ballast and various track devices could be tried under conditions that would give valuable comparative results, while the attendant expense would be very much less than if the college or university were required to own and operate the entire track at its own expense. In the four years of his college course the earnest student could thus acquire a fund of information that would be invaluable to him in later life, and upon graduation he would probably be at once competent to act as section foreman, or at least as assistant foreman. At the same time he could perform much of the instrumental work now delegated to the engineer of maintenance of way.

It may be urged in objection to this plan that it places the safety of traffic and the lives of passengers in the hands of young and irresponsible students upon the experimental section; but with a competent instructor in charge who could, at the same time, be held amenable to the rules of the railway company, as in the case of any other official, this objection is without force.

Any plan that will acquaint the beginner with the little details of his work will make him a better official later on, whether it be as roadmaster, superintendent or engineer of maintenance of way. Surely a superintendent who has had an engineer's training will make a much better official—other things being equal—than an untrained man.

It is probable that there are other and better methods of attaining the desired results than those I have proposed, and it is with the hope that a thorough discussion of this subject by the members of this society, whose object is the advancement of engineering education generally, may bring such methods to light, that I submit the above.

DISCUSSION.

Professor Allen said he desired that the paper should not be passed by without some discussion and word of comment. He believed that the time had come when much of the work of the administration of railroads must be done by graduates of engineering colleges. He thought that, in very many of the departments of railroad work, it would be found desirable or necessary to depend upon graduates of engineering schools, and the maintenance of way is, of course, an important part. The speaker said that the movement to employ engineering graduates upon maintenance of way is not confined to Texas, nor to California, but that it had reached the conservative East; and the Boston and Maine R. R. Co. is very glad to secure as section hands, graduates of the Massachusetts Institute of Technology, and this Institute has not yet reached so great an eminence as to prevent its graduates from accepting such positions. The speaker had during the day received a letter from a graduate of the Institute informing him that he had engaged in work of this kind on the Boston and Maine Railroad. In two or three years past, the Institute had contributed a number of men for this sort of work, and it was the speaker's opinion that the best way for the young men to get their experience is by engaging as section men rather than by having similar work carried on in any way as part of the instruction in the college. He was inclined to think that such practical experience can best supplement the work of instruction. The speaker was told by a roadmaster of one of the large divisions of the Boston and Maine Railroad, a man of several years' standing as a graduate of the Institute, that they needed for roadmasters, men with engineering education; a surveying education simply, did not secure the sort of men wanted in that position. There was necessary what he called the engineering education. It seemed to the speaker that the training given in a good course in civil engineering is the foundation requisite;

he was inclined to believe that the best way to supplement that is not by additional instruction as to maintenance of way details to any considerable extent, but to have the men, after graduation, enter upon such work in a subordinate capacity and become familiar with all the details of the work as it is carried on by the railroads.

PROFESSOR WHITNEY (by letter) said that Mr. Sloan, Chief Engineer Illinois Central Railway, had expressed himself as highly pleased with the experiment of introducing college graduates into the section forces. He had found that, apart from the demand for muscle in such work, there is from time to time need for instrumental work, the keeping of accounts, and the making of written reports, all of which are executed very properly by the young graduates, thus relieving them from much of the more laborious work. It has also proven expedient to form parties for extensive new surveys largely by recruits from this source. Much of the survey work for the elevation of the St. Charles Air Line in Chicago was managed in this way. Mr. Sloan stated that about one half the time of such men would be occupied with these experiences; that he had not found it necessary to retain these young men on sections longer than from four to six months before withdrawing them into the engineering department, as vacancies occurred; and that additional confidence was felt in much of the work of those young men who had had this training.

The writer thought there is little doubt of the probable willingness of most railroad companies to adopt some such system of training maintenance of way men.

From the standpoint of the young graduate there might be, at first thought, a natural hesitation in voluntarily associating with section men. Yet, when looked at from the double standpoint of proper laboratory work, and a summer's outing, there is no more objection than can be urged against some surveying parties. There is vastly more to be learned in a month of such work than is often had from a whole season at the rod, as some have served. The writer thought it would be well for the young man to spend one vacation, preferably that between the junior and the senior year, on this work, thus shortening the time, or doing away with the necessity for additional time, after graduation. The writer did not agree with the author of the paper in the statement that maintenance of way should be divorced from the operating department. Engineers make the very best operating officials; and, as has been shown on the Pennsylvania Railroad, the operating department furnishes the greatest number of most satisfactory rewards in the way of desirable positions.

The railroad field of activity clearly illustrates what is more or less apparent in manufacturing and other lines of engineering industry, that the greatest prizes within reach of the engineer frequently hang just outside the oftentimes too narrow enclosures of technical ground.

REPORT OF THE STANDING COMMITTEE* ON ENTRANCE REQUIREMENTS FOR THE YEAR 1897-98.

OUTLINE OF WORK DURING THE PAST YEAR.

Members of the Society will perhaps recall that the report of the Committee presented at Toronto a year since was necessarily somewhat meagre and defective in form on account of the enforced absence of Professor Marvin, the chairman of the committee. In his absence, the committee reported in a general way as to the criticisms obtained during the year on the extended report presented to the Buffalo meeting of 1896. To the gratification of the committee, the recommendations which had been laid over from the Buffalo meeting were thereupon taken from the table and adopted, with the further vote that the same committee continue as a standing committee to carry out the recommendations adopted.

It seemed to members present at Toronto that the work up to that time, although of great magnitude, had been comparatively straightforward, but that the future policy of the committee presented grave questions and should be laid out with much caution. To their great regret Professor Marvin, who had devoted so much thought and energy to his arduous duties as chairman of the committee, found other cares so burdensome that he was finally obliged, in January, to resign the chairmanship of the committee. By appointment of President Johnson, President Mendenhall of Worcester was added to the committee and the secretary was appointed acting chairman.

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*Professors H. W. Tyler, J. J. Flather, J. P. Jackson, Mansfield Merriman, and T. C. Mendenhall.

If a personal reference may be permitted, the acting chairman begs to state that in accepting his new responsibilities he disclaimed the ability to prepare a satisfactory report for this meeting on account of his previous acceptance of the Local Secretaryship of the meeting of the American Association. He would hardly have accepted at all but for the serious difficulty he believed any other appointee would find in taking up the unfamiliar threads so late in the year.

In April, proof of a circular was submitted to other members of the committee and subsequently mailed to all the colleges included in the list of 1896. The objects of the circular as finally determined upon were these:

First—To submit to the colleges for criticism the definition of principles which, in the judgment of the committee, ought to govern any system of admission by certificate.

Second—To secure from the colleges information as to changes in their entrance requirements since the preparation of the 1896 tabulations.

After mature consideration it seemed to the committee unwise to attempt the specification of details in particular entrance requirements at this time. The circular issued read as follows:

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

COMMITTEE ON ENTRANCE REQUIREMENTS.

BOSTON, May, 1898.

DEAR SIR:

The special committee on Entrance Requirements was appointed at the Brooklyn meeting of the Society in 1894. The committee has made a painstaking study of the whole subject and has presented annual reports, the principal one at Buffalo in 1896. The following important recommendations of the committee as then presented were unanimously adopted by the Society at the Toronto meeting of 1897:

> The committee, therefore, advises that the Society appoint a standing committee on Admission to Engineering Colleges to be charged with the execution of the recommendations following:
>
> (*a*) The formulation, with due regard to the interests of non-engineering colleges, of a sufficiently definite outline of work in each of the subjects named on page 166(¹), so that preparation in any subject shall be available for any college requiring that subject. In many subjects this formulation should provide for a minimum and a maximum requirement, *the latter always including the former.* This qualitative uniformity within the above list would be an enormous gain, and should, in the opinion of the committee, meet all legitimate demands of the colleges and all just complaints of the schools. The practicability of such a method has been shown in the work of the Commission of Colleges in New England, particularly in English.
>
> (*b*) That the formulation of requirements by this committee be sent to each engineering college with an invitation to consider it carefully in issuing its statement of requirements.
>
> (*c*) That the formulation of principles that should govern admission by certificate, as found on page 170(¹), be also sent to each college for consideration in defining its requirements.
>
> (*d*) That to all colleges whose requirements correspond with sufficient closeness, the committee recommends coöperation by interchange of evidences of preparation.

(¹) Proceedings, Volume IV.

(*e*) That the standing committee report annually to the Society as to changes in requirements for admission to engineering colleges.

For the present year the committee will not attempt the formulation of entrance requirements in particular subjects or the promotion of coöperation between colleges by interchange of evidences of preparation, but will confine itself to the further consideration (1) of the proper basis for admission by certificate, and (2) of changes in entrance requirements of engineering colleges.

1. **Statement of Principles of Admission by Certificate.** Comment and criticism of the following points included in the report of the committee are invited with special reference to existing usage and tendencies in your own institution. It is believed that institutions not now accepting certificates will also be interested in this information.

(*a*) As the primary essential, personal visitation and inspection on the part of the college of the school asking a commission.

(*b*) This commission to be limited as to time and reissued only after reinspection, or on full knowledge of the condition of the school.

(*c*) The reservation of the right of the college to withdraw the commission for cause shown.

(*d*) Certificates to show in detail the extent of the ground covered and actual time spent in each subject and to contain the personal recommendation of the superintendent or principal.

(*e*) Students received on certificate to be required to make up any deficiency in preparation that may appear in any certificated subject.

(*f*) The college to cultivate friendly relations with its accredited schools and to make clear, through publications and conferences, just what its requirements are.

2. **Changes in Requirements.** The report of the committee included a careful tabulation of the entrance requirements for eighty-nine

colleges as given in their catalogues for 1894–5, that for the following year being substituted in a few cases. To bring this tabulation up to date, it is requested that a brief statement be given of any changes that have been made during the past three years. Information as to the reasons for changes made will be especially welcome.

(*a*) Changes in Mathematics.

(*b*) Changes in other Science Subjects.

(*c*) Changes in Modern Languages.

(*d*) Changes in Literary Subjects.

(*e*) Other Changes.

In begging your courteous attention to the above requests, the committee desires to remove any appearance of undue inquisitiveness or intrusion. It is believed by the committee that the condition of secondary education throughout the country is such that important changes are in actual progress and that others will come in the near future. It is exceedingly desirable that these changes should not be made without due consideration of the interests and rights of the great number of students who are looking forward to an engineering education. It is much to be feared that these interests and rights will suffer unless they are carefully guarded by coöperative action on the part of the Engineering Colleges. Such coöperation we ask you to join us in promoting.

J. J. FLATHER,
Purdue University.
J. P. JACKSON,
Pennsylvania State College.
T. C. MENDENHALL,
Worcester Polytechnic Institute.
MANSFIELD MERRIMAN,
Lehigh University.
H. W. TYLER,
Massachusetts Institute of Technology.

Committee
on Entrance
Requirements.

Please address replies to H. W. TYLER, 491 Boylston Street, Boston.

Replies have been received, in some cases after several requests, from about seventy colleges out of more than one hundred. While the committee regrets notto have complete returns, it is of the opinion that for present purposes numerical completeness is not of the first importance. It may not unfairly be assumed that the seventy colleges reporting represent all phases of criticism on the certificate plan and that the other thirty are not likely to have made radical changes in their entrance requirements. Moreover, the committee can not regard the replies as of more than qualitative significance, at any rate without more careful analysis and comparison than it has been possible to make.

2. *Analysis of replies in regard to principles governing admission by certificate.*

In general the principles designated as (a), (b), (c), (d), (e) and (f) are accepted without qualification, some of them being naturally regarded as self-evident. It was, of course, expected by the committee that this would be the case, but it was hoped that instructive comments would often be offered in regard to the application of these principles. That this has not been done by our correspondents to a greater extent may be ascribed to the just and universal repugnance to filling out blanks of this kind with which so many of us are burdened. To many of our correspondents, however, we desire to acknowledge renewed indebtedness for painstaking and suggestive replies. The following criticisms have been selected as of interest:

"(a) As the primary essential, personal visitation and inspection, on the part of the college, of the school asking a commission."

This principle has, on the whole, elicited more criticism than any other. Some of the various phases of opinion are these: Colleges of some age and strength, with a constituency largely local, not only believe in the principle but appear to exercise it with thoroughness. This is notably the case with many of the state universities. Other institutions which exercise the certificate system believe in visitation but do not exercise it for lack of means. Some of these are able to depend upon the state universities to exercise it for them. Several important institutions object to visitation on the ground of the great extent of their constituency. Most of these depend largely or even wholly on examinations rather than on certificates. The number of institutions by which this principle is so fully carried out as to be of high value would seem to be comparatively small. The committee recognizes that the principle in question is open to abuse where there is active competition between colleges.

Instructive comments from particular colleges may be quoted.

Leland Stanford Jr. University—"Personal visitation not without obvious disadvantages: by no means a primary essential, but, on the whole, probably desirable: impossible to a university having a large and general constituency."

Columbian University—"The inspection should not be limited to the material equipment and to the outlined courses of study offered by the school, but should include an inspection of the instructors with reference to their training and their ability to teach."

Iowa State College—"It is proposed to have a committee of the College Section of the State Teachers' Association, in which all the state colleges are represented, prepare an accredited list of high schools. This committee would give the personal visitation and inspection."

University of Kansas—"There is a movement on foot among our high schools to adopt this sort of plan: each school to request the University to send out an inspector from the faculty at the expense of said school. We feel the need of such a system."

University of Nebraska—"The University has now for the first time an inspector of all accredited schools."

Columbia University—"Of questionable value: (1) imposes much labor on college faculty for inspection; is of little use unless thorough; (2) quite impossible for large institutions drawing students from a wide territory and from many schools; (3) co-operation impracticable to diminish this labor, as the value of the inspection depends so largely on the personal equation of the inspector, who should be an expert in pedagogic matters."

New York University—"Visitation desirable, but careful inquiry may do more than a day's visitation."

North Dakota Agricultural College.—"In this State admission to the State University and Agricultural College, is determined by a High School Board, elected by the teachers of the Sate. The college also sends an examiner."

Ohio State University.—"The University has a system of "recognition" which involves regular reports from the preparatory schools, and "recognition cards" are sent to all graduates of such schools, whether the graduates express an intention of entering the University or not."

Lafayette College and Brown University appear to depend to some extent upon inquiry through their alumni living in the vicinity of the schools in question.

Virginia Polytechnic Institute.—"Personal visitation very important, especially as regards equipment of preparatory schools for teaching elementary physics, etc."

"(b) This commission to be limited as to time and re-issued only after re-inspection, or on full knowledge of the condition of the school."

"(c) The reservation of the right of the college to withdraw the commission for cause shown."

"(d) Certificates to show in detail the extent of the ground covered and actual time spent in each subject and to contain the personal recommendation of the superintendent or principal."

"(e) Students received on certificate to be required to make up any deficiency in preparation that may appear in any certified subject."

The discussion of these four topics presents much less variety and interest. Some colleges practicing visitation consider that it should be done annually; others are content with triennial or quinquennial visitations; others are guided by changes in curriculum or in the instructing staff. The college's right to withdraw the certificate privilege is unquestioned.

In regard to certificates there are two well defined views:—on the one hand, the desire for full details; on the other hand, the preference in favor of supplying full information in the statement of entrance requirements and throwing the responsibility as to their fulfilment upon the certifying teacher. The personal element of the certificate is to some extent thus determined. It is also noted in one or more replies that personal replies by teachers are liable to involve unpleasant personal consequences to them.

The committee would now amend (e) by inserting after the words "make up" the phrase "at a definite early date." The statement seems not to have been understood in the same sense by all colleges. Different colleges have different modes of making up deficiencies, but none admit that they are overlooked.

"(f) The college to cultivate friendly relations with its accredited schools and to make clear, through publications and conferences, just what its requirements are."

There is little dissent from the principle here expressed, but the variations in its application are at least as wide as those under (a). Those colleges which live up to (a) most fully are necessarily in closest touch with the secondary schools. On the other hand, a college may do everything possible in the way of explaining its requirements in accordance with (f) but do no visitation whatever.

The importance of notifying schools of the performance of their certified candidates after admission to college is emphasized by a number of answers and might well have been explicitly included in the statement of principles by the committee. Such evidence must be of value to a conscientious teacher and many of the colleges depend largely upon it in their continuance of the certificate privileges. The University of

Illinois, which appears to discharge its functions toward secondary schools with great care, mentions an annual conference with the teachers, while the University of Wisconsin refers significantly to an annual banquet.

GENERAL COMMENTS ON THE CERTIFICATE SYSTEM.

Mixed systems appear to some extent, and there are sporadic indications of their gaining in favor. Particular institutions report, for example, that they can not count on sufficiently thorough mathematical preparation for engineering work without testing applicants by examination. On the other hand, at the Massachusetts Institute of Technology, which has ordinarily accepted no certificates, the interesting experiment has been initiated of adding a group of electives, one of which must be offered, and is expected to be represented by certificate, although in some cases examinations may be taken if preferred. The certification of a particular subject does not in any case relieve the applicant from any required work at the Institute; it is rather accepted as collateral evidence of the breadth of his preparation.

The University of New Brunswick feels sure that admission by certificate would lower the standard of the schools in that province.

Columbia has increased the applicability of the elective principle by accepting the New York Regents' certificates, provided in every case that these represent forty-eight academic counts, and include fourteen in mathematics, eight each in English, French, and German.

The University of Pennsylvania is eliminating admission by certificate, while its neighbor, Lehigh, has the subject under careful consideration with a possible tendency toward greater liberality.

3. *Changes in Entrance Requirements.*

Nine institutions report advances in algebra. These are as a rule colleges of relatively low requirements working their way to higher standards. Nearly twice as many report advances in geometry, and these again, belong to a considerable extent, to the same class. In one case additional geometry takes the place of trigonometry, in another, of advanced algebra. Six report advances in history, twelve in modern languages, and fourteen in English, where there seems to be also some increased vogue of the New England requirements. On the other hand, at one college an alternative for the New England requirements has just been introduced.

Changes in science requirements are almost too various to classify. The tendency to introduce or increase science requirements appears to be somewhat general, although not yet far advanced.

Drawing has been added at five colleges; manual training has been discontinued at two.

Very important changes have been announced for the Lawrence Scientific School of Harvard University, the general expressed intention of the changes being to bring the entrance requirements to a level with those for admission to the college, with considerable latitude in their selection.

Two colleges on the committee's list, Coe College and the Louisiana Southern University, report that they are not teaching engineering.

4. *Suggestions as to Future Work of the Committee.*

In the judgment of your committee, its future usefulness depends to a considerable extent upon its enlargement. The functions of the committee, up to this time, have been essentially correspondence and analysis, for both of which the small working committee served best. The further execution of the recommendations adopted in 1896 requires, however, something more. It is necessary on the one hand that the committee should have as many points of contact as possible with the general educational world. On the other hand it is necessary, if we are to deal with formulations of requirements in particular subjects, that our membership should include the best specialists in those lines, either as a part of our general committee or as such a federal organization of sub-committees as those, for example, which carried on the work of the committee of ten.

With these needs in view, it is accordingly suggested that the committee be enlarged to consist of eleven members and that this committee be authorized to secure the coöperation of such sub-committees as it may deem necessary; membership in such sub-committees not to be restricted to members of this society.

The committee prefers to offer these as suggestions rather than as positive recommendations, fully appreciating that their adoption implies the assumption by the society of important duties and responsibilities in secondary and higher education which may or may not be regarded as a legitimate part of its work. On the other hand, it is undeniable that this assumption of responsibility has been already involved in the adoption of the recommendations of 1896.

Respectfully submitted,
H. W. TYLER,
Acting Chairman.

DISCUSSION.

PROFESSOR TYLER said he wished to add only a few words supplementing the report. He said the important points were these: The Society voted in 1897 to appoint a Standing Committee to proceed to the execution of the recommendations of the Committee. This year, the speaker continued, it had seemed wise to the Committee to undertake only (c) and (e); namely, the distribution of the Society's recommendations in regard to the admission by certificate, and the collection of information as to changes made since its first tables were prepared. The Society is now at the parting of the ways; it has already set its face in one direction; but the speaker thought the Society should again consider whether it would undertake all the formidable amount of work outlined in the report, or whether it preferred for the present, at any rate, to continue work of the same character as had been done thus far; that is, investigation, analysis, and report. The speaker said he regarded the work of investigation as important and valuable, and while the enlarged vocations of the Committee might be still more important, they were too difficult to be attempted except with the active co-operation of every member of the Society. In this sense it had therefore been recommended that if the Society adhered to its purpose the Committee be enlarged to consist of eleven members, representing a wide range of institutions geographically; a wide range in the kind and quality of work; and in particular that the members should represent different branches of required study—mathematics, English history, etc.; and further, that the Committee should be authorized to organize a system of sub-committees, of which the membership should not be restricted to members of this Society, but that an attempt should be made to institute such committees of specialists as might coöperate in the definition of requirements.

The speaker, in conclusion, said that in speaking a little doubtfully of the wisdom of this larger undertaking he did not wish to be regarded as questioning the Committee's own recommendations; but he was unwilling that the Society should acquiesce unqualifiedly in the suggestions which the Committee made with hesitation.

Professor Johnson said that the question was whether the Society should undertake the serious work of trying to formulate conditions of requirements to be recommended to the various schools; and, if so, whether the Committee should be enlarged, as recommended, to eleven members, with permission to organize subcommittees, calling in persons not members of that Committee. But the virtual question was whether or not the Society was prepared to undertake what might be called executive work rather than simple advisory work or the collection of information; that is, whether the Society should undertake to do something with this information.

Professor Allen moved that the matter of the recommendations of the committee and the appointment of a larger committee or committees be referred to the new Council with full power to act. The motion was seconded.

Professor Landreth spoke in favor of the recommendations of the Committee and urged the undertaking of the work proposed in its report. The speaker said he hoped he should be permitted to differ from the reference by the Chair to such work as executive. It seemed to him that if this Society adopts a measure, no matter how much or how little is involved, it is simply advisory in character. It seemed to the speaker that with the latitude which the motion carries with it a sufficient range is offered the schools, and therefore this can only be considered as strong advisory action. The speaker went on to say that at the Brooklyn meeting he had strongly advocated the appointment of the Committee; that he had then seen the need of some influence of this nature; and that since that time he had had opportunity to observe the effect of the influence of the committee in its preliminary work; it had enabled administrators and faculties to take action which will make the work of the Society even more important in this respect—this action being the urging of the necessity for higher requirements. The trustees and official managers of colleges are between two fires; the necessity of doing a high grade of work, and that of gaining a large number of students. It is evident that it is desirable to give strong support to the demand for high requirements, and to preserving the four or five years for the purely technical and the necessary literary culture, by anticipating as much of the preliminary training as possible; and the Committee's action had done a great deal by showing that there is a strong need for just this advancement. The speaker said that he was heartily in favor of taking this step, which he thought would still further increase the usefulness of the work without entailing that degree of arbitrariness which might be feared; and he heartily indorsed the motion to attempt this advisory work. He was not however prepared to speak on the proposal to enlarge the committee.

Professor Bull also expressed the opinion that the work of the Committee should be continued along the lines suggested in the report. He also thought it quite possible that the curricula of the various high schools and academies may be changed; that there are indications of such changes. The opportunities given the future engineering student while in the high school are not what they should be, and an effort should be made to change the curriculum in such a way as to make it better for this particular work. The speaker instanced the preparation for modern languages: nearly all the various high schools in this country furnish four years of Latin and two of German, and no more; but for the engineering student this should be reversed. If the high school can afford to furnish instruction for four years in Latin, an equal time should be given to German: and in this way the study of German in the engineering schools might be dropped entirely, and the time could thus be taken for something else.

The motion to refer the recommendations of the committee to the council, being then put to vote, was carried unanimously.

A COURSE IN HIGHWAY ENGINEERING FOR CIVIL ENGINEERS.

BY W. R. HOAG.

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Highway building is both a science and an art.

As an art it has always had few zealous workers; as a science it has received tardy recognition in every country and by every people. The art has been practiced with commendable fidelity where the science, stimulated by wise rulers or the general progressive spirit of a people, has led the way. The Romans practiced little else than the crudest art of road-building. Tresaguet can be said to have introduced some little scientific method into his highway construction. The English people, in the latter part of the eighteenth century, became aroused to the enormous tax their impassable roads were imposing upon them, and the modern science of highway building had its rise. The names of Telford and MacAdam are inseparably connected with this epoch.

From the broad earthen ways over which the Egyptians are said to have transported by rollers the huge stones for their walls and temples, down through the extravagantly solid and broad military roads of the Romans, to the neat and efficient broken stone roads of to-day, the abstract science may be said to have made considerable progress; and if we allow that the modern railroad, with its welded steel rail surface, is but another step in the onward movement, the total advance seems quite abreast with the general industrial progress of the world. But the latter class of highways are so far in advance, in all that seems desirable or even attainable, (until aerial navigation is realized), that it seems a long look into the future when our common highways shall serve the purpose for which they are made, as perfectly as the railroad now fulfils its *raison d'etre.*

Why this tardiness in a matter which so materially affects all the people? Has the science of road-building been so indifferently formulated that it has not been adequate to the demands of the age?

It is not my purpose to trace the reasons why our highways have usually been the last to receive their share of attention from the constructive genius of our people. To use a highway figure: rather than to spend much time philosophizing as to how we came to be in the mire, it is my purpose in this brief paper, to call attention to means by which we can be very helpful in showing the people the "better way," even if we do not carry it to the point of actual construction.

Much good might result from an inquiry into the reason why this country, fully abreast of the nations of the world in most of the peaceful arts (and not behind at least one in the art of war), should be so far down the scale in the practical art of road-building. Some of these reasons, however, will appear as we seek to show how the class of men represented by this society can become most helpful workers in the cause of better roads.

Assuming that one worthy object, if not the most important, of an engineering education is to prepare young men to advance the many varied interests with which their professional engagements bring them in contact, we hold that that training which simply leaves the graduate with a knowledge of how to build the best roads with the material obtainable or at hand at an allowed cost is sadly deficient.

It is the merest beginning, or rather, it is simply the top sheaf. All of the preliminaries which have much to do with the actual building of highways must have been arranged.

If to-day we could give employment to all the engineering knowledge and skill which we now have, a comparatively few years would see a marvelous change in our highways. The art of road building can now be practiced but partially by the civil engineer, since the people are slow now to seek his services.

This desire must be created before the strictly professional services of the engineer will be required. We need road missionaries rather than road engineers. The people must be taught the money value of good roads and the burdensome tax which poor roads impose and always collect, before they will seek out engineering services to better their condition. We grant this to be outside the usual and, perhaps, the legitimate province of a civil engineering training, but it is believed that Minnesota does not stand alone in the need of this preliminary, missionary work. It is with the thought that as a type we represent a good majority of the state institutions and that as such we are bound to supply what we find wanting, even though it may mar somewhat an ideal prosessional course, that we have chosen to present this phase of the subject rather than the usual scientific aspect treated by our text books. We might say, in passing, that we find Professor Spaulding's book an excellent general guide. We supplement it with topic studies and essays, drawing upon various sources of information as well as observation of roads and streets in process of construction and those under traffic.

The University of Minnesota first introduced its work in highways in 1895. Doubtless we have here represented institutions which entered the field much earlier, and there are, perhaps, few who now devote as little time as we to instruction in the science of road building. We are giving a fair share of the allotted time to what might be termed the missionary preliminaries. We give in all thirty classroom hours and twenty laboratory hours to this work.

Safe bridges and buildings we must have, cost what they will; safe and reliable engines and motors alone will find market; electric machinery must be safe and efficient to find acceptance with the people. But the contrary holds with respect to our highways. In them we tolerate anything that is passable. Guessing what the condition of the road will be, the farmer gauges his load to fit it and trusts the rest to his lash and a kind

Providence. The unique position which the public highway thus holds in our public economy makes instruction relating to it of an unusual character, and it is upon this phase of it alone we care to speak. Indeed, having established this proposition, in some measure, at least, we might well leave the methods by which this missionary work shall be accomplished to older heads, allowing each to adapt methods to local needs and conditions.

I will, however, venture a few suggestions of how the work has been carried out to meet the wants as we have seen them in Minnesota, believing that they will be helpful in other states, Massachusetts and New Jersey excepted.

To bring the student into proper sympathy with his subject, a lecture or two on the historical development of highway construction and a like number on the general question of transportation, with emphasis on the part played by the common highway, is recommended. Next should be considered all the forces at work in the home state for the betterment of its highways.

This would naturally begin with our national office of road inquiry, which is doing so much, with the little allotted it by Congress, for the encouragement of better methods in road building, the wide circulation of road literature, and a general marshaling of the different state forces for a united movement for improved highways. All the agencies within the state should be very fully treated, such as cycle clubs, state engineering societies, good roads organizations, state institutes, agricultural papers, etc.

If the state has an efficient system of highway construction and maintenance, its plan should be studied in detail. If it has not such, the defects of the laws under which it is vainly seeking to improve its highways should be made prominent, and some good model (such as Massachusetts or New Jersey) should be fully discussed and analyzed.

No opportunity should be lost to attend good roads conventions or societies at which are to be read and discussed papers on any phase of the subject. Have the student prepare papers on some particular division of the subject. I find agricultural papers are glad to give space to these, and thus a double benefit results.

Visits to permanently good roads and habitually poor ones should be made, in case local conditions make the former possible, and the causes which have led to the different results discussed and identified as far as possible.

The instructor should engage actively in all movements in the state having any interest in the cause. I am glad to note that a number of instructors in civil engineering have already entered this missionary field, and are making good additions to our highway literature.

The number should be greatly increased. Every instructor in civil engineering, having in immediate charge this line of work, should be a strong political factor in this cause, which has already done so much for the material advancement of the world.

Correct notions on the administrative side of road building are sadly deficient in many states, and particularly in one with which we are well acquainted. By exercising the power to which his position justly and naturally entitles him, the educator can help create an activity which will soon bring into requisition our graduates who have thus been well prepared for all the duties coming to the highway engineer.

The present agitation of the road question has become of such popular interest in Minnesota that one of our leading dailies, The Minneapolis Times, very gladly devotes from one to two columns in each Sunday issue to good roads matter. We have conducted this column for the past two years, and find that the little work connected with it is no burden, but rather a pleasure and an inspiration. We heartily recommend some such activity for any who desire to extend their usefulness in this comparatively new field of engineering activity.

It might be held by some that this work would very probably fall to the department of political science. Certain local situations might render this expedient.

No saving of time to the student, however, would result; and among the large number of other questions treated, that of highway economics would become more or less subordinated. The instructor in engineering would, at the same time, lose that contact with this missionary part of the work which we regard as highly essential.

Then let us take a little time from the abstract science of road building and devote it to the missionary economics of highway administration. This will result at once in an increased interest and knowledge in the general science, and soon will follow a call to one graduate from the great practical school of the state to practice the art for which the state has fitted him. Thus this attractive field will be opened to our graduate; rich reward in improved highways will result to the state, and another laurel of usefulness will be added to one of the professions for whose advancement this Society stands pledged.

DISCUSSION.

Professor Allen said that for a number of years it had been a pleasure to him to take a strong interest in matters of highway construction and improvement, and of highway education. In reading the title of the paper, he had wondered whether its purpose would be to treat of a complete course in highway engineering, leading to a degree, perhaps of Bachelor of Science in Highway Engineering; or whether, on the other hand, it would refer to the special instruction given within some other established course, like that of civil engineering. It had seemed to the speaker that in very few colleges, if any, is there necessity, at the present time. for a complete course in highway engineering. The work of highway engineering, the building of good roads, is very largely an art, and the instruction as to road construction must be to a considerable extent instruction as to facts. Such instruction, while it may be necessary and proper, fails to contain in a very large degree the training element. Our engineering colleges, under the pressure which exists, are forced to insist upon doing as much work as possible, in the training direction, and it seems not to be feasible in most cases to carry the work of highway construction through a very extended course requiring a very large number of hours. There are certain principles that apply especially to highway work which readily introduce the element of the training value. But the basis of a course in highway engineering should be a thorough and effective training in civil engineering, which constitutes a very complete and substantial foundation upon which to build, in whatever instruction it is proposed to give especially and directly in highway engineering. The speaker believed that the time is coming, however, when the demand for highway engineers will be so strong that we must provide an education more definitely directed to that work than any now given. The time may not be far distant when it will be found desirable to omit some of the subjects which now form a part of the course in civil engineering, and to substitute for them subjects that will be of special value in highway engineering. It had occurred to the speaker that among the first of those subjects would be perhaps a more complete and thorough study of geology, and, incidentally, a reasonable amount of time might be devoted to mineralogy; further, following out the general plan suggested by these two subjects, it may be possible that the highway engineer should become more or less expert in chemistry and should devote somewhat more attention to physical laboratory work.

As a result, the highway engineer will be in position to know better how to secure the proper material for use in highways, and in the case of any material which comes to his notice, he may be better able, himself, to determine, by chemical and physical analyses, whether the material is that which is well adapted for any special locality or for any special use. The speaker thought that the engineering colleges could not afford, at present, to devote an undue amount of time to furnishing students with facts in connection with which principles are not very largely involved; not even to facts which are especially valuable to highway engineers; the best time for the highway engineer to secure his facts, under present conditions, is after graduation.

THE CLAIMS OF SANITARY SCIENCE TO A PLACE IN THE CURRICULUM OF ENGINEERING EDUCATION.

BY WILLIAM T. SEDGWICK,

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In the language of biology, education is the higher adaptation of the organism to its environment. The whole process of adaptation, or the fitting of the organism for successful living, may be said to have three principal phases, namely, *birth*, *education*, and *experience*. To say that anyone is fitted by these three for a particular place or a particular work is to say nearly all that can be said of adaptation. True, we may and often do add to these, temperament, health, manner, rank, wealth, and other qualities, as being important and desirable, but any and all of these—unless we except health—are clearly of secondary consequence. Birth often carries all of them with it; education may impart some of them and improve others; while experience may yield to the wise a breadth and culture which shall be their full equivalent.

Let us dwell for a moment on these three great factors or phases of adaptation in order to see the more clearly the real function of education, of which

Engineering Education is only an important subdivision and Sanitary Science only one possible constituent or element. The first is *birth*, a term usually held to mark the beginning of life, but in reality marking the end of a long period of preparation. Out of the spherical living egg or cellule, step by step and day by day, is built *in utero* that most consummate of all machinery, the human mechanism. While growing in mass it also rapidly differentiates within and its wonderful framework becomes knit together,—bone and muscle and nerve; gradually it is furnished with an elaborate pumping machinery, in the shape of heart and vascular apparatus; with ventilating machinery—both plenum and vacuum—in the respiratory system; with cavities devoted to food supply and water supply, in the alimentary canal; and elaborate sewerage and sewage disposal systems in kidneys and intestine. Receivers much more wonderful than those of the telephone cover the skin, the retina and the endings of gustatory, olfactory, and auditory nerves in tongue, nose and ear. Transmitters of high efficiency are provided in the voice, the gestures, the facial muscles and the hand. Locomotive apparatus of delicate adjustment is got ready, and some provision is even made for similar mechanisms in the future, to take the place of this one when it shall have become worn with age and death shall stop the vital machinery. Thus, even before birth, Nature takes the first, the most difficult, and the only absolutely indispensable step in that adaptation of the organism to its environment which must subsist if it is to live and to do anything, however humble and unimportant, as a human being. It is a melancholy reflection that even Nature does not always succeed. Some human beings die before they are born. Defects in material or in construction are as fatal before birth as afterward. Faulty machinery works no better here than elsewhere, and the record of still births is a record of a want of adaptation of organisms to environments.

Thus it happens that at birth and long before it, Nature, working through parents and the race by the mysterious influences of heredity and more directly by those processes which, taken together, we call ontogeny, shapes and moulds the plastic, growing, living mass and supplies those instinctive powers which enable the young organism to make its entry into the world as an independent being, roughly adapted to its new environment. Thus, in fine, it is slowly but surely fitted for the life it has to live. And so adequate is the preparation—in which, it should be carefully noted, the educator plays not even the slightest part—that the vast majority of the human species, and all animals below the human, are able to dispense with almost all further adaptation excepting that which comes from experience, and to go through life successfully without any of that higher adaptation which it is the duty and the privilege of the educator to supply.

At this point it is a temptation to reduce our three principal factors or phases of adaptation to two, namely, birth and experience, and to merge education with the latter, of which it might almost be made a part. But while this would be a wholesome lesson for those educators who unduly magnify their office and its possibilities, we need not, fortunately, go so far. For there are grades and degrees of adaptation. Between that adaptation which suffices to secure a bare subsistence, and that which marks perfection, there is a great gulf fixed; and it is the high calling of education to enable men to rise above the former and to strive unceasingly for the latter. It is then not merely some adaptation to environment which education seeks to bring about but rather a more perfect, or higher, adaptation.

Obviously the curriculum of education is only a series of steps designed to bring about such higher adaptation. It begins by endowing the young with special tools or instruments—the implements of higher education—namely, the arts of reading, writing, and numbers. If drawing is added, as it should be, this is only another kind of writing. A few—too few— of the facts and phenomena of nature, sometimes including man and the universe, are then brought to the attention of the child; and these simple lessons combined with certain desirable customs of manners and morals—such as decent behavior, punctuality, obedience, and veracity—few and brief, but infinitely precious as compared with no lessons at all, make up the higher adaptation of the great majority of mankind in even civilized and educated communities. For the grocer, the butcher, the cobbler, the motorman, the conductor, the common soldier, the baker, the common laborer. and a thousand other useful and indispensable kinds of men. this education is an invaluable means of higher adaptation to their environment. Without it they would be illiterate, and able to do only the meanest kinds of manual labor.

Passing by all other kinds of education, let us now turn at once to that known as professional. Here. again, as always, the test of the curriculum must be its efficiency in promoting the higher adaptation of the organism of its environment. So, also, in any special case of professional education, such as that of the engineer, the curriculum must be judged by its efficiency in producing or favoring such adaptation; and, finally, the claims of any subject, such as sanitary science, to a place in that curriculum must be determined, and determined solely, by its known or probable efficiency in promoting the higher adaptation of the engineer to his environment, that is, to the work of his profession. We may remark in passing that this test will doubtless exclude it from many science courses, for it is hard to see how the higher adaptation to his profession of (for example) the mechanical or electrical engineer, the physicist, the mathematician or the geologist, would be materially promoted by a course of lectures on sanitary science and the public health. Professionally it would aid these men very little if at all; and if it is of no aid professionally it has no longer any special claims, but only the general one of general usefulness, to rest upon. In this case it must take its place beside a score of other useful but not indispensable subjects and loses, with them, most of its specific educational importance.

With the civil engineer, the mining engineer, the architect, the chemist, the biologist, the chemical engineer, the sanitary engineer, the naval architect, the agriculturist, and the general student of science, on the other hand, the case is very different. These men in their professional or special work are likely to have to do with problems involving directly the welfare of the community, or, as in the case of the mining engineer and naval architect, with smaller but still considerable masses of men under special and peculiar conditions. To the higher adaptation of these men to their environments, sanitary science, in my opinion, may powerfully contribute, and I now desire to show how and, to some extent, how much. I shall not need to insist on the high value of health, and I shall assume that the prevention of disease is admitted to be so desirable as to be of the very first importance. It follows as a matter of course that those who have it in their power to do so should do their utmost to promote the public health. I now propose to show that those in the professions enumerated have this power, and that they should be far better able to do their duty in this direction—in other words would be far better adapted to their environments professionally—if they were thoroughly grounded in the principles of sanitary science.

A mighty change of opinion in respect to the nature, the origin, and the prevention of disease has lately taken place in the minds of men. Malthus in his famous "*Essay on Population,*" written almost exactly one hundred years ago, says "Diseases have been generally considered the inevitable inflictions of Providence," and Cruden, in his great "*Concordance*" to the Bible, first published near the middle of the last century states that "Disease and death are the consequence and effect of sin; this is the idea which we have of them from Scripture." He continues:—"The ancient Hebrews, who were very little versed in the study of Natural Philosophy and not much accustomed to recur to physical causes and consult physicians when they were sick, imputed their diseases generally to evil spirits, the executioners of divine vengeance. If their infirmities appeared to be beyond what was usual, and the causes of them were not known to them, they did not fail to say that it was a blow from the avenging hand of God. * * * In the New Testament, the cause of many diseases is attributed to the Devil. It is said there that the Devil had bound the woman who had been bowed down for eighteen years. * * * We are told of a dumb devil and of another that could scarce speak, that is to say, which caused these infirmities in those who were possessed by them. * * * The Apostle Paul ascribes the infirmities wherewith he was afflicted to an evil angel. * * * It was the avenging angel that drew his sword against the people, and smote them with the pestilence. * * * The Philistines were smitten with an ignominious disease for not treating the ark with that respect that it deserved. * * * There are a great number of diseases recorded in Scripture, which were sent by God in the way of punishment for sins."

These ideas are typical of the general attitude of mankind towards disease and its causes and prevention until within a very few years. To-day, on the contrary, disease is regarded as a condition or a process as truly natural, and as truly subject to natural laws. as other conditions and processes, such as health and growth or rain and sunshine. With this profound change in our point of view of the origin and causation of disease it has rapidly come to pass that we are nowadays taught to seek the sources of infection, not in supernatural or devilish or mysterious and incomprehensible agencies but in impure food and drink, in dirt, dust and sewage, in foul air, in overfeeding or wrong feeding, in overwork or idleness. Moreover, this revolution is so profound and on the whole still so novel that, in my opinion, all who are to follow the professions indicated should, if it be in anywise possible, fit themselves more adequately for work in which these ideas may be of direct practical importance, by attending at least a brief course of lectures and demonstrations given by someone who is fully alive to the changes referred to and fully informed as to the highly important and practical bearing of the subject upon modern civilized life.

In order that I may make clear exactly what I mean, and what in my judgment such a course should be, I will briefly state precisely what is done in fifteen lectures of one hour each in my own course in "Sanitary Science and the Public Health" at the Massachusetts Institute of Technology. The course falls in the last half year of the senior year of our four-years' courses. It is required of all sanitary engineers, architects, biologists and general-course students and taken also by some civil engineers, chemists, and others. It has grown from small beginnings to an attendance of about one hundred. The course consists entirely of lectures, and, owing chiefly to the absolute lack of any acceptable text-book or reference book and the pressure of other subjects, no final examination is held. It is an easy, interesting, and popular course of fifteen weeks with one lecture each week, one hour in length; but in spite of its brevity and simplicity I firmly believe that it is one of the most timely, most helpful, and therefore most valuable, of the shorter courses of the school. The stereopticon is used almost constantly after the first two or three lectures; diagrams are employed in large numbers; demonstrations are given of bacteria and the methods of their cultivation; water, pure and polluted, is shown and commented upon; sewage, before and after purification, is exhibited; and every effort possible is made to impress the reality, the simplicity, and the practical importance of the subject upon those who take it.

In the opening lecture it is pointed out that the body is essentially a mechanism: that health and disease are merely conditions of this mechanism; that disease may proceed from poor construction or poor materials—and thus be intrinsic or *constitutional*,—or from unfavorable external or environmental conditions, such as polluted water or infected milk, and thus be extrinsic or *environmental*. It is shown that constitutional diseases, such as heart disease or apoplexy, can obviously be but little influenced by public sanitation, while those such as typhoid fever, which proceed from the environment, may, in theory at least, and to a great extent also in practice be readily prevented. Finally, the ultimate function of hygiene and sanitary science is shown to be "the prevention of premature death." Incidentally the causes of death as laid down in registration reports are discussed, and disease, rather than old age,—the only normal cause of death,—is found to be the principal agent of death.

In the second lecture, disease and theories of disease, ancient and modern, are stated and commented upon. Modern survivals of the daemonic theory of savagery are noted in the preventive medicine involved in the horse shoe over the door and the horse chestnut and rabbit's foot in the pocket. "Possession" by "devils" is touched on, and the cure of disease by their casting out. The theories of disease which flourished side by side with the wonderful art, literature, and eloquence of the classic age of Greece and Rome, and with the "science" of Aristotle, Ptolemy, and Pliny, are described. In particular the Hippocratic theory of "the four humours" of which so many traces still linger in our everyday phraseology, *e. g.*, "melancholy" (black bile), "sanguine" (bloody), "phlegmatic" (phlegm) and "jaundice" (yellow bile),—the four humours of Hippocrates. In this lecture also Arabian and Mediaeval theories are referred to, as well as the gradual "return to nature" in the Renaissance period under Paracelsus, Stahl, Sydenham, etc. A rapid sketch follows of progress in the 18th century under Haller and Morgagni; of the curious and mystical speculations of Hahnemann; and, in the 19th century, the wonderful results following the discovery of the achromatic microscope objective. The rise of the "germ" theory of fermentation soon after, in the hands of Louis Pasteur, leads directly to the "germ," or zymotic, theory of disease. Pasteur's great work on the diseases of wine, of beer, and of silk worms is briefly dwelt upon, and its first fruit, sanitary (or aseptic) surgery, is described.

The next lecture is given up to a detailed exposition of the rise and vast significance of the new science of bacteriology. The labors of Koch in its establishment are recited in considerable detail and the lecture ends by showing how further and more recent work has converted the earlier *zymotic* (or ferment) into a *zymotoxic* (or ferment-poison) theory, in which it is not so much the germs as their poisonous products (*toxins*, *ptomaines*) which are now regarded as the true sources of disease. This portion of the subject concludes with a demonstration that thus the newer theory brings us back parallel to, and alongside of, familiar and well known phenomena and natural laws of chemical poisoning; so that the mystical, supernatural halo that still hangs like a fog about many of our ideas of disease is somewhat lifted, if not wholly dispelled, by a reduction of the phenomena to a scientific basis.

With so much of theoretical and historical introduction as a preface, we then pass on to the consideration of infection and contagion in general; what they are, precisely: the ways by which they find entrance into the body: the resistance which it offers to their invasion, (vital resistance, susceptibility, immunity, etc.): the vehicles by which they are conveyed, (air, water, sewage, milk, ice, dust, dirt, etc.); and their sources in the environment. The fundamental importance of sewage and sewerage in this connection is duly emphasized, and with this the lecture ends.

We now take up, *in extenso*, the fundamental problems of modern life in respect to the dissemination and control of infection and contagion, one lecture being devoted to the consideration of sewage as a vehicle of disease and of its proper disposal and purification. Here, as in many other cases in this course, we are fortunate in having at hand the Lawrence Experiment Station of the State Board of Health, from which specimens, examples, and illustrations can be readily and abundantly drawn. The *principles* involved in filtration, chemical and electrical precipitation, the "biological" and "septic" processes, etc., etc., are readily expounded and understood upon the somewhat elaborate theoretic basis laid down in the earlier lectures.

Drinking water as a vehicle of disease is dwelt upon in the next lecture, together with extended illustrations of epidemics of typhoid fever and Asiatic cholera due to the pollution of public water supplies. The natural sequence is to treat, in the next following lecture, the principles governing the establishment and conservation of purity in public water supplies. Ice supply, the pollution of ice, and ice supply and the public health; milk supply, the pollution of milk, and milk supply and the public health, form the subjects of the next two lectures. Then comes a consideration of the part played by dirt, dust and air as vehicles of disease, with natural conclusions on the philosophy of cleanness. Methods of the examination of air for bacteria, and of the air supply of buildings and of structures such as tunnels, are touched upon. The relations of filth to disease are pointed out and the "pythogenic" theory of Murchison is criticised.

The remaining lectures deal with disinfection and disinfectants and methods for testing their efficiency; with the applications of bacteriology to the preserving of food and other materials, such as timber, and the prevention of decomposition and decay; the disinfecting powers of chemical agencies (such as fire and poisons), of physical agencies (such as heat, cold, dryness, light and electricity), of mechanical agencies (such as filtration, sedimentation, etc.) and of biological agencies (such as starvation, old age, "unfavorable environments," etc.); with certain popular errors of belief in regard to the causes of disease; and with the use and abuse of vital statistics in sanitary science.

As a result, I believe that those who follow the course come to have literally a realizing sense of what disease is, its causes, and how,—when it is possible to do so,—it may be effectually prevented. I believe that they can henceforward relapse only with difficulty if at all into the idea that infectious diseases differ essentially except in complexity, from any other natural phenomena. They will not be content to regard an epidemic, or even a single case of typhoid fever, as any more an "act of God," or any more inscrutible, than a flash of lightning or an earthquake; while it will seem to them far more under human control.

We may now ask: is this brief course likely to be so efficient in promoting the higher adaptation to their environments of those who take it as to entitle it to a place in the curriculum of engineering education? My own conviction is not only that it is so, but that in certain branches of such education it is absolutely indispensable. Above almost all other men engineers need to-day not only knowledge but judgment, intelligence and wisdom. They must not only act but advise, command, persuade. Their opinions must, therefore, be sound. They can not afford to make mistakes. To them, the community, as it differentiates and becomes more and more specialized, looks with ever increasing confidence for advisers, supervisors, and administrators. In almost all matters affecting masses of people, things sanitary now play a part, not only fundamental but universal; and if engineers are to be adapted to the environments in which their profession is likely to place them; especially if they are to be highly and thoroughly adapted to their work, there can be no question, it seems to me, that they should be familiar with at least the fundamental principles of sanitary science and the public health. Having the modern points of view in regard to health and disease; infection and contagion; epidemics and disinfection; public supplies being recognized as public dangers as well as public safeguards, they should be in any community sources of higher intelligence, higher wisdom. They should be more calm in the presence of excitement, more sane in the presence of unreason, more wise in the presence of fools; and these are qualities which in their possessors tend to make the currents of life, for individuals as well as communities, flow more smoothly and in deep and quiet places rather than in shallow and dangerous rapids.

A few years ago I was called to a neighboring city in which typhoid fever was prevailing. I found the city officials of engineering training deeply troubled and anxious. The popular excitement was great. Ignorant persons were writing to equally ignorant newspapers blaming the sewers, the water supply, the garbage-disposal system—above all, those in charge. An hour's inquiry sufficed to show that whatever the cause of the fever might be, it could not possibly be either sewers or drinking water or dumps. The officials were immensely relieved. They once more faced their fellow citizens boldly, as innocent men. Eventually it proved that the trouble came from milk—skimmed milk—derived from a creamery in which a man lay sick with the fever. This man had driven a wagon and delivered from it skimmed milk. Wherever that wagon had left the milk there was fever, but nowhere else; and when he got too sick to go his rounds, the fever stopped altogether. A very small amount of knowledge of sanitary science would have enabled the officials in charge of water, sewers and garbage to make an adequate defense. Without it they were helpless, and at the mercy of the ignorant. What they needed was simply the knowledge and ability to meet the occasion—in brief, a higher adaptation to their environment, which an acquaintance with the fundamental principles of sanitary science would have readily supplied.

DISCUSSION.

Professor Merriman said that for a number of years it had been one of his duties to give instruction in sanitary engineering, and he had found it necessary to supplement the text-books by giving informal talks on bacteria and the modern theory of disease. He hoped that the fifteen lectures of Professor Sedgwick might be put into book form, so that this important branch of sanitary work might be more readily brought to the attention of engineering students. The speaker thought there could be little doubt but that sanitary engineering is the most important subject taught in the practical part of a civil engineering course, on account of its important relations to the community. He referred to Professor Thurston's remark that one advantage of moderate entrance examinations lies in enabling young men to enter earlier upon active work, and thus render greater service to the state and community. The speaker noted that this remark had much force, because the median age of the white population of the United States is about the same as that of graduation from a college course. According to a recent investigation that he had made, the median age of this population was 18.6 years in 1850, 19.3 years in 1860, 19.9 years in 1870, 20.9 years in 1880, 22.0 years in 1890, and it might be inferred that it would be about 23.1 years in 1900. This increase in median age is one of the triumphant results of the work of hygiene and sanitary science during the latter half of the nineteenth century.

Mr. Burrage said, with reference to the statement in the paper that sanitary science could not feasibly be connected with a course in mechanical engineering or electrical engineering, that he had just been arranging a course of lectures on railroad sanitation in connection with the course in railroad engineering at Purdue University. Upon looking into the matter, he had been surprised to find how many and various are the points at which sanitary science touches the railroads, in the construction and ventilation of the cars and in the construction and the sanitation of the railroad stations. The speaker said that, except in the largest cities, few of the railroad stations throughout the country have comfortable and convenient sanitary arrangements, and in the small towns they are simply filthy. He thought a course in sanitary science would be very valuable to mechanical engineers or to railroad engineers in connection with the work on railroads and railroad shops. A good example of attention to these matters is set by the Pennsylvania Railroad, which furnishes pure water to its employees at a cost of about ten thousand dollars per year, employing chemists and biologists to make frequent analyses. Another point the speaker wished to bring up was the fact that in some States, as in New England, engineers of all kinds are filling places upon boards of health; while in many of the western states it is required that only medical men should comprise these boards. With the large number of competent sanitary engineers available for the work, it seemed to the speaker that this restriction is too conservative on the part of these states.

Mr. Kent also referred to the statement in the paper that a course in sanitary science could not well be given to mechanical engineers, but that other courses must be selected. It seemed to him that Professor Sedgwick's course of fifteen lectures should be considered not as a course in sanitary engineering strictly, but as a course in liberal culture. The speaker referred to former discussions in the meetings of the Society as to how much "liberal" education should be given in engineering schools, in which the general opinion had favored a certain amount of liberal training, as in languages, English literature, and social science. It seemed to the speaker that there could be no more valuable liberal training than a course of lectures such as had been outlined in the paper on sanitary science courses. The speaker could not conceive of anything in Greek, or Latin, or metaphysics, or any foreign literature, that would broaden the students' ideas and be such a revelation to them as would this course of lectures, wherein would be found some chemistry, biology, physics, hygiene, statistics, etc.; and it therefore seemed to him that instead of confining this subject to sanitary engineers it might well be broadened out so that nearly all students should be obliged to take it as a part of their liberal training.

Professor Sackett said that he agreed very fully with the remarks of Mr. Kent. He thought that until graduation from a college is required before entering a technical school, the technical schools are under obligations to give something of liberal education. In a great many schools there is required, not only of the engineering students but of others as well, a course in general chemistry which might be directed along some such useful lines as indicated by Professor Sedgwick. The speaker thought that engineers are very often too modest in the community, but their modesty is frequently due to a lack of knowledge as to why sanitary work should be undertaken, and a knowledge of the causes of disease and health. He believed that a course in general sanitary measures should be in the curriculum of every college; that a series of lectures of a general character should be given, in order that the students graduating from our colleges may give better support to the boards of health in the different communities; may understand that the inspection of the sanitary arrangements of buildings, and its cost, is all for the benefit of the public; and may understand why milk and food should be tested and inspected, etc. The speaker cited an instance in which one of the boards of health of the State of Indiana stated that it was useless to attempt to carry out certain reforms, because the people at large did not understand the measures that the board was trying to promote. The speaker therefore believed that every college course should have a series of good lectures, short and general in character, or long and specific, according as the work is directed towards the mechanical engineer, the civil engineer, or the sanitary engineer, or all students, in order that the graduate shall become a more useful factor in society.

Professor J. B. Johnson said that the most important thing in this world is life, and it would therefore seem that the most vital part of any education is that which pertains to the prolongation and preservation of life. He sympathized with the wish that had been expressed to have the course of lectures referred to put into shape for general use; and he had pleasure in announcing that Professor Sedgwick was preparing for publication something which would be of value along that particular line.

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